FEEDING A NUCLEAR GIANT: FERNALD AND THE URANIUM PRODUCTION SYSTEM, 1943-1989

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Abstract

The Fernald Feed Materials Production Center, located 18 miles northwest of downtown Cincinnati, Ohio, refined and produced uranium products for the American nuclear weapons program from 1951 to 1989. In the course of its Cold War mission, Fernald polluted the surrounding countryside and was responsible for increased illnesses among workers and nearby residents. Using a case study approach based largely on archival materials, this thesis places Fernald within the Cold War context, explains the creation of the uranium production system in the United States, and explores the conflict between Cold War production goals and protection of health and the environment. Despite its critical importance to nuclear weapons production, Fernald has received scant attention from Cold War or environmental historians. While the Fernald site has been remediated into a green space, medical studies have found elevated rates of cancer among the local population as well as continuing environmental contamination.

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I would like to thank Shane Bell and the staff at the National Archives Atlanta Branch for their professionalism and assistance while accessing the archives. I would also like to thank my classmates for their proofreading, revisions, and support; Frank Klaassen, Jim Clifford, and Katie Labelle for teaching me how to be a historian; Geoff Cunfer, Lindsey Banco, and Andrew Watson for their work as committee members; Martha Smith for her excellent guidance, support, and supervision; and especially Megan Langlois, who might not want to hear about uranium ever again.

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Introduction

In 1980, Richard Heatherton retired from a career with the United States Department of Energy that spanned four decades. Beginning in the late 1940s as an industrial hygienist with the Atomic Energy Commission (AEC), Heatherton worked within the Health and Safety Division to determine the amount of radiation workers were receiving on the job.[1] Twenty years after retiring as the director of health and safety at the Fernald Feed Materials Production Center, Heatherton reflected on his experiences in an interview with *USA Today*: "The purpose was production… Health and safety was not the chief purpose of these [operations]."[2] Heatherton's words captured the impossibility and irony of his task. American nuclear weapons production was motivated by Cold War tensions and an arms race with the Soviet Union. The facilities that made up the atomic weapons complex were devoted to the singular task of weapons production. Yet, the AEC maintained a health and safety division and employed people like Heatherton to ensure that its workers were safe and that damage to the surrounding environment was kept to a minimum. As Heatherton's own reports and recollections indicate, however, this was not the legacy of the American nuclear weapons program.[3] Instead, the historical record shows that the AEC and Department of Energy (DOE) knowingly and willingly sacrificed worker safety and environmental cleanliness in favour of weapons production. This thesis traces that history through two generations of uranium refining facilities, with an emphasis on the Fernald Feed Materials Production Center outside of Cincinnati, Ohio. This case study demonstrates how the

[1] Richard C. Heatherton, "Radiation, Radon, and Dust Survey of Operations Essential to the Storage of K-65 in the Tower," November 27, 1950, Box 12, Series 27, Record Group 326, NARA, Atlanta.
[2] Peter Eisler, "Toxic Exposure Kept Secret," *USA Today,* 2000.
[3] Heatherton, "Radiation, Radon, and Dust Survey."

AEC and its contractors prioritized the production of nuclear weapons while neglecting the environmental and biological harm caused by the refining of uranium during the Cold War.

The lack of a coherent national pollution policy in the United States before 1970 contributed to the negative environmental and health consequences at plants like Fernald which were unexplored until the 1980s. Despite established departments and regulations within the AEC, the uranium production system polluted the local water, soil, and air across the continental United States and beyond. Untethered by federal regulation and pressured by Cold War tensions, uranium refineries were free to negotiate pollution policy with local regulators. Before the establishment of the United States Environmental Protection Agency (EPA) in 1970, individual American states often invested the powers of pollution regulation within their state boards of health. Since existing environmental legislation was relatively weak in the first half of the 20th century, environmental regulators often turned to negotiations with the polluter to establish acceptable pollution limits.[4] As the Fernald case demonstrates, the AEC and DOE exploited the weak regulatory powers of the state boards of health and used their own strong classification powers to maintain high production levels of uranium and to hide pollution from local populations.[5]

As a result of rapid progress in physics research during the 1930s, and the onset of the Second World War, the United States began a crash program to produce an atomic bomb in 1942.[6] Physicists around the world had concluded that the creation of an atomic bomb was

[4] Martin V. Melosi, *Effluent America: Cities, Industry, Energy, and the Environment* (University of Pittsburgh Press, 2000), 64-66

[5] "Report of Ground Contamination Study Committee," 30 September 1962, Box 5, Series 27, Record Group 326, NARA, Atlanta, 20-21.

[6] Richard G. Hewlett and Oscar E. Anderson Jr., *A History of the United States Atomic Energy Commission, Volume 1: The New World, 1939-1946* (University Park, PA: Pennsylvania State University Press, 1962), 52.

theoretically possible, but the United States did not have the industrial capacity to produce one. Before the onset of the war, uranium was usually treated as a waste product of radium mining and plutonium simply did not exist in nature. Uranium oxide was processed on a small scale by a handful of American factories to create glazes for ceramics and pigments for glassware, and pure uranium metal was used a few grams at a time in the nation's universities.[7] Scientists quickly deduced that, instead of micrograms distilled in laboratories, the Manhattan Project would require kilograms of pure uranium produced in refineries. When asked about the feasibility of the project, the pre-eminent physicist Niels Bohr remarked that the United States would have to become "one huge factory."[8] By 1945, this characterization was accurate. Manhattan Project administrators created a transnational system of no less than ten major factories in the United States that together took uranium ore from Canada and the Belgian Congo and transformed it into the most powerful weapons ever created.

During the Manhattan Project, the chemical process by which uranium ore was processed into highly-enriched uranium (HEU) and plutonium was a complex, multi-step operation involving several intermediate products. Black oxide (triuranium octoxide, U_3O_8) was the first product in the supply chain, the result of a refining process that separated uranium from other impurities found in the ore. Black oxide was produced at Port Hope, Ontario, by Eldorado Mining and Refining, and at the Linde Air Products factory in Tonawanda, New York. Black oxide was shipped from Ontario and New York to the DuPont Deepwater Works in Deepwater, New Jersey, and the Mallinckrodt Chemical Works (MCW) in St. Louis, Missouri. At Deepwater and MCW, black oxide was converted first to orange oxide (uranium trioxide, UO_3), and then to

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[7] Robert Bothwell, *Eldorado: Canada's National Uranium Company* (Toronto: University of Toronto Press, 1984), 81.
[8] John M. Findlay and Bruce Hevly, *Atomic Frontier Days: Hanford and the American West* (Seattle: University of Washington Press, 2011), 4.

brown oxide (uranium dioxide, UO_2). At this point, brown oxide was shipped to the Harshaw Chemical plant in Cleveland, Ohio, to be converted into green salt (uranium tetrafluoride, UF_4). The Harshaw plant, after 1944, subsequently processed green salt into uranium hexafluoride (UF_6), the direct feed material for the uranium enrichment processes at the Oak Ridge facility in Tennessee. In a separate stream, the Mallinckrodt Chemical Works and the Electro-Metallurgical company plant in Niagara Falls, NY, produced pure uranium metal from a magnesium reduction process. This uranium metal was then shipped to the Hanford Works in Washington State to produce plutonium.[9]

This system did not cease operations with the end of the Second World War. While there was some uncertainty surrounding the future of nuclear weapons immediately after the conflict, the rise of Cold War tensions encouraged the United States to pursue an aggressive expansion of nuclear weapons production. In February 1946, the Deputy Chief of Mission at the American Embassy in Moscow, George Kennan, authored the famous “Long Telegram” to the American State Department in Washington. One of Kennan’s central arguments within the telegram was that the leaders of the Soviet Union were not motivated by logic and thus Soviet aggression could only be contained with a sufficient military threat from the United States.[10] Harry Truman reflected these arguments in 1947 when he appeared before Congress to request $400 million dollars in military and economic aid to Greece and Turkey.[11] Whereas the U.S. had been

[9] *Manhattan District History*, Book VII, Volume 1, secs. S9-S13.

[10] The telegram arrived at a time of heightened tensions between the Soviet Union and the US and was widely circulated among American government officials. Gregg Herken, *The Winning Weapon: The Atomic Bomb in the Cold War, 1945-1950* (Princeton: NJ: Princeton University Press, 1981), 141.

[11] Turkey, at the time, was being pressured by the Soviet Union to relinquish control of the straits between the Mediterranean and the Black Seas. Greece was in the midst of a civil war, with a strong communist movement. Senior American officials argued that without support from the United States, both Greece and Turkey would fall under Soviet influence. Walter LaFeber, *America, Russia, and the Cold War, 1945-2006* (New York: McGraw Hill, 2008), 59-61.

producing a handful of nuclear weapons each year until 1948, the production schedule quickly increased to hundreds, and then thousands of nuclear weapons per year.[12] With the end of the American nuclear monopoly in 1949, American production of nuclear weapons became critically important to the U.S. containment strategy.[13]

With the increase in production came the increase in demand for uranium. The discovery of massive deposits of uranium in Ontario, northern Saskatchewan, and the western United States coincided with a construction boom in uranium processing facilities.[14] The Atomic Energy Commission built two uranium refineries at Weldon Spring, Missouri, and Fernald, Ohio, two uranium enrichment facilities at Paducah, Kentucky, and Portsmouth, Ohio, a bomb core factory at Rocky Flats, Colorado, and a weapons assembly plant at Pantex, Texas. Replacing all of the temporary factories operated during the war by 1955, these new facilities consolidated fissile materials production, and reflected the shift from the slow production of several prototype weapons per year to the mass production of ready-to-use models during the 1950s. As a result of the increase in both recoverable uranium deposits and the facilities to process them, the U.S. increased its stockpile from 1,169 warheads in 1953 to 22,229 in 1961. Only a year later, during the Cuban Missile Crisis, the American arsenal numbered some 25,500 nuclear weapons.[15]

In the 1950s, people living in northern Saskatchewan probably felt as if they had little in common with the citizens of the Marshall Islands. Indeed, it is difficult to imagine two climates and landmasses less alike. Yet, Canadians occupying the frigid subarctic and Marshall Islanders

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[12] Hans M. Kristensen and Robert S. Norris, "Global Nuclear Weapons Inventories, 1945–2013," *Bulletin of the Atomic Scientists* 69, no. 5 (September 1, 2013): fig. 2, 78.

[13] Michael D. Gordin, *Red Cloud At Dawn: Truman, Stalin, and the End of the Atomic Monopoly* (New York: Farrar, Straus and Giroux, 2009), 22–23.

[14] T.E. Murray et al., "Fourteenth Semi-Annual Report of the Atomic Energy Commission," July 1953, NNSA/NSO Nuclear Testing Archive, https://www.osti.gov/opennet/detail.jsp?osti-id=16360377, 1–11.

[15] Hans M. Kristensen and Robert S. Norris, "Global Nuclear Weapons Inventories, 1945–2013," fig. 2, 78.

residing on sun-soaked atolls both lived at either end of the American nuclear weapons production chain.[16] The production of thousands of nuclear weapons required uranium mines, refineries, enrichment plants, nuclear reactors, chemical separation plants, metal fabrication plants, weapons design laboratories, and testing sites. While the American government constructed much of this infrastructure, it also relied heavily on the private sector in the first ten years of the atomic weapons program. Established industrial facilities concentrated in the eastern United States joined remote uranium mines and newly-established atomic cities to form the world's first nuclear weapons production system.

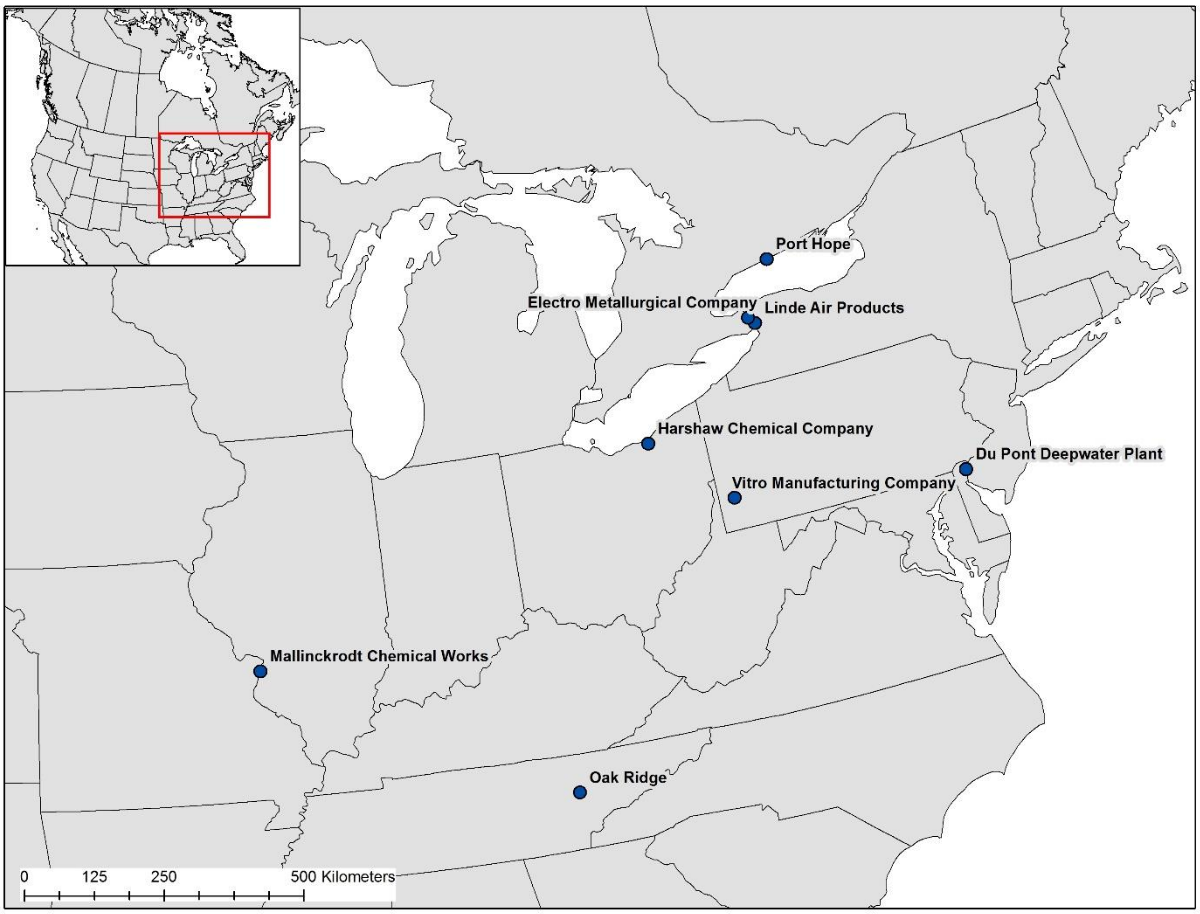
Across the production system, processing, refining, and manufacturing processes at various facilities caused environmental damage and poisoned people's bodies. By the end of the Cold War, American efforts to produce nuclear weapons had produced 24 million cubic meters of radioactive waste, as well as 1.5 billion cubic meters of contaminated water, and 73 million cubic meters of contaminated soil.[17] Health data, while less exact, still paints a grim picture. Since the beginning of the 1990s, the Centers for Disease Control (CDC) has conducted six radioactive dosage reconstruction projects, each detailing a separate nuclear weapons facility. The CDC estimates that there will be 11,000 fatal cases of cancer in the United States as a direct

[16] Although this thesis initially uses the terms "production chain" and "production complex" interchangeably to refer to the physical sites that produced atomic weapons, "production complex" is a more expansive term that includes national laboratories and testing sites in addition to uranium mining and refining sites. Later on, the thesis adopts the term "production system" to reflect a more dynamic understanding of those same sites. "Production system" is a more inclusive term that acknowledges the multitude of actors and interests that worked together to produce atomic weapons during the Cold War.

[17] This does not include some 143,848 cubic meters of radioactive soil and debris from Enewetak Atoll, nor 500 tons of radioactive debris and an unknown amount of radioactive soil from Bikini Atoll now stored at Runit Island. See US Department of Energy, *Linking Legacies*, 71, 83-86.

result of nuclear testing.[18] Dose reconstruction projects at other sites are less conclusive, and often leave residents and workers wanting for information that is more concrete.[19]

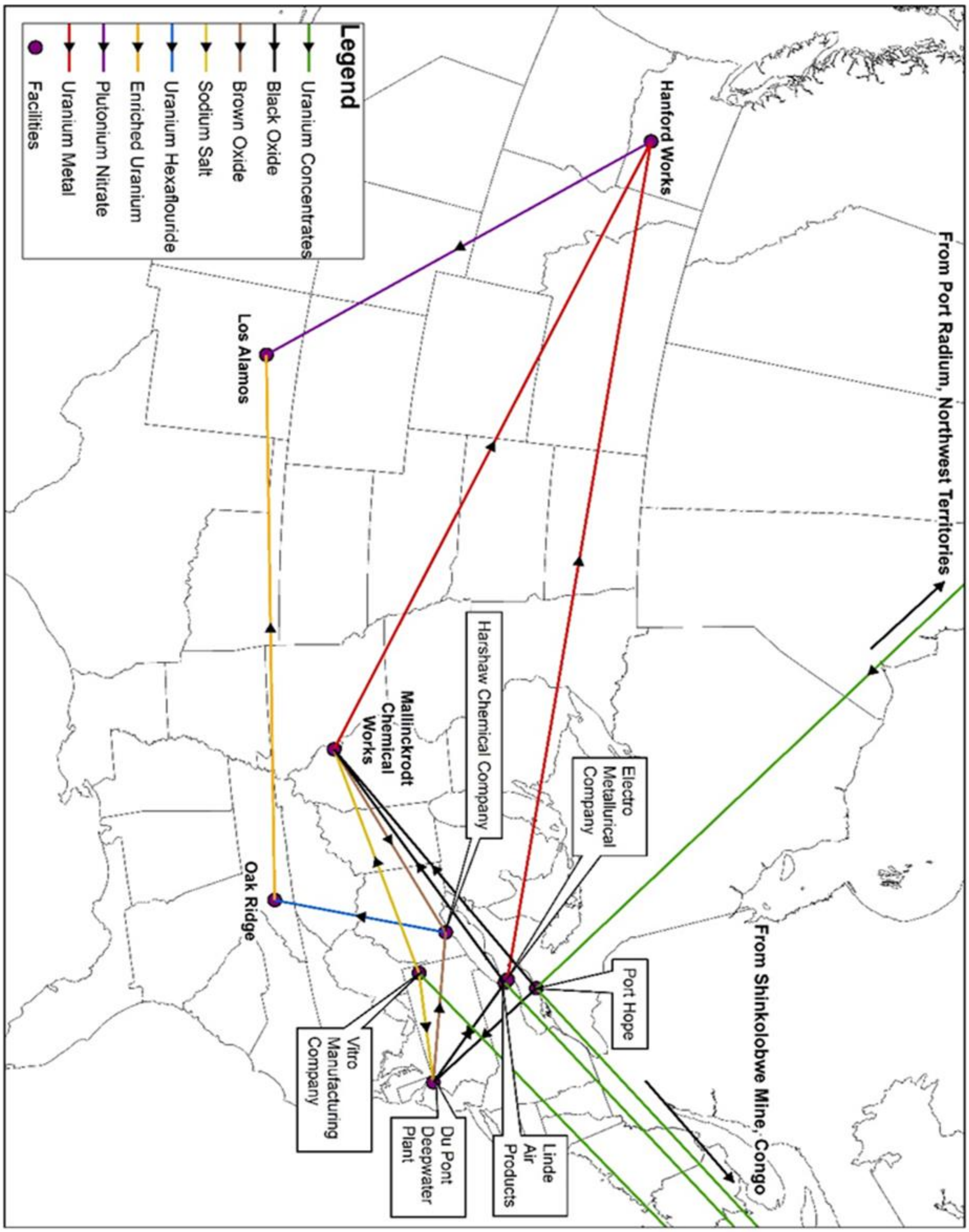
Figure 1.1 Principle Uranium Refineries in the Eastern United States and Canada by 1944
Author: Steven Langlois, Historical GIS Lab, 2018



[18] Department of Health and Human Services, Centers for Disease Control, National Cancer Institute, "Report on the Health Consequences to the American Population from Nuclear Weapons Tests Conducted by the United States and Other Nations," May 2005, 4.
[19] Centers for Disease Control, "Dose Reconstruction Activities and the Cold War," https://www.cdc.gov/nceh/radiation/public_health_research.htm

Figure 1.2 American Nuclear Weapons Production Complex, 1 January 1945

Author: Steven Langlois, Historical GIS Lab, 2018



Beginning with the first publicly available report on the Manhattan Project in 1945, the Smyth Report, most scholarly publications regarding the production of atomic weapons focused on the role of scientists.[20] Using major scientific breakthroughs to drive the narrative, historians concentrated on particular scientists and wrote about their laboratories and their relationship with Washington. Rebecca Schwartz argues in her 2008 Ph. D. dissertation that the Smyth Report had a lasting impact in the historiography and influenced historians to write about the creation of the atomic bomb as a particularly scientific endeavour.[21] This is not to say, however, that scholars ignored other aspects of nuclear weapons. Historians such as Martin Sherwin and Gregg Herken discuss the atomic bomb in conjunction with larger themes such as war and international diplomacy.[22] Richard Hewlett and Jack Holl's official history of the AEC recognizes that, at least for a period of time, the primary function of the agency was to produce fissionable materials for the manufacture of nuclear weapons,[23] something that required more industrial might than scientific brilliance. Still, Hewlett's and Holl's volumes are guided by the administrative narrative of the AEC, intersecting where applicable with the political, scientific, economic, and diplomatic aspects of atomic bombs.

Due to several factors, nuclear historians began to shift their focus in the 1990s. After five decades of intense secrecy, Department of Energy Secretary O'Leary began a policy of openness in response to revelations of human plutonium experiments during the Cold War. A series of scandals at nuclear facilities, the end of the Cold War, and a general heightened

[20] Henry DeWolf Smyth, *Atomic Energy for Military Purposes* (Princeton: Princeton University Press, 1945).
[21] Rebecca Press Schwartz, "The Making of the History of the Atomic Bomb: Henry DeWolf Smyth and the Historiography of the Manhattan Project" (Princeton University, 2008), iii.
[22] Martin J. Sherwin, *A World Destroyed: Hiroshima and Its Legacies* (Stanford: Stanford University Press, 1973); Herken, *The Winning Weapon*.
[23] Richard G. Hewlett and Jack M. Holl, *Atoms for Peace and War, 1953-1961: Eisenhower and the Atomic Energy Commission* (Berkley: University of California Press, 1989), 7.

sensitivity to environmental damage resulted in a turn towards an understanding of nuclear facilities and sites in terms of legacy. In 1997, Peter Bacon Hales published *Atomic Spaces: Living on the Manhattan Project*. Hales looks at the social, spatial, and environmental dimensions of the Manhattan Project and encourages scholars to view the non-military aspects of atomic bomb production. John M. Findlay and Bruce Hevly advanced the historiography further in 2011 with *Atomic Frontier Days: Hanford and the American West*. In this book, Findlay and Hevly examine the cultural connection between Hanford and the wider American West. Kate Brown's celebrated *Plutopia: Nuclear Families, Atomic Cities, and the Great Soviet and American Plutonium Disasters* was published only two years later. Detailing the environmental and biological harm wrought by the American and Soviet plutonium factories, Brown's work is characterized by careful research and powerful narrative. In 2016, Martha Smith-Norris published *Domination and Resistance: The United States and the Marshall Islands during the Cold War*. Examining the impact of American nuclear weapons testing on the Marshallese, and the ways in which they organised to resist such treatment, this monograph expands the historiography to include remote testing sites in the larger atomic production system. [24]

Histories from the last twenty years are thus different from earlier scholarship in terms of scope and focus. Whereas the first generation of nuclear historians were interested in explaining how and why the United States built and used nuclear weapons, the current generation is more focused on the legacy of that production, especially in local or regional contexts. While earlier histories were told on a national scale, the latest monographs are often written about a single

[24] Peter Bacon Hales, *Atomic Spaces: Living on the Manhattan Project* (Urbana: University of Illinois Press, 1997); Findlay and Hevly, *Atomic Frontier Days*; Kate Brown, *Plutopia: Nuclear Families, Atomic Cities, and the Great Soviet and American Plutonium Disasters* (Oxford: Oxford University Press, 2013); Martha Smith-Norris, *Domination and Resistance: The United States and the Marshall Islands During the Cold War* (Honolulu: University of Hawai'i Press, 2016).

facility or site in the nuclear supply chain. As a result of this shift, historians have paid much closer attention to the environmental and health consequences that developed locally at each AEC facility. This thesis builds upon the recent historiographical developments by exploring the health and environmental consequences of the Fernald Feed Materials Production Center and its relationship to the Cold War.

Michael Silverman's 2000 dissertation, "No Immediate Risk" provides a nuanced framework for understanding nuclear weapons production in the United States. Instead of referring to the collection of mines, factories, laboratories, and testing sites as a "nuclear weapons complex," Silverman argues that this collection is much better understood as a nuclear weapons production system. He makes a strong case that the atomic production system was not as monolithic and dominant as former historians have suggested. Instead, the nuclear weapons production system is better understood as a federation, including multiple groups of diverse actors, both inside and outside of the system itself. Silverman uses this framework to explore ideas of environmental safety and acceptable risk within the production system.[25] Influenced by Silverman's framework, this thesis explores the ways in which different historical actors inside and outside the atomic production system understood environmental damage and medical harm. My core research questions include: what role did the Fernald refinery play in the U.S. nuclear weapons production system? What were the medical and environmental impacts of uranium refining at the Fernald plant during the Cold War? What was the local community's response to Fernald's history of pollution and radioactive contamination?

[25] Michael Joshua Silverman, "No Immediate Risk: Environmental Safety in Nuclear Weapons Production, 1942–1985," Ph.D. Dissertation, (Carnegie Mellon University, 2000).

This project makes use of archival collections, both digitized and physical, that contain documents for the period 1942 to 1963. The Atlanta branch of the American National Archives and Records Administration holds many of the records from the Oak Ridge Operations Office (OROO). The OROO was the headquarters for the Feed Materials Division of the Atomic Energy Commission, the particular division in charge of refining uranium into "feed materials" for the plutonium and enriched uranium plants. This rich collection of documents forms the evidentiary basis of this thesis. Documents in this collection highlight the general history of the uranium production complex, and the decisions that were made by the people in charge of it. In the Atlanta archives, I found documents that support my argument that the administrators of the AEC knew how quickly uranium polluted the surrounding environment and how they repeatedly failed to seriously address this problem.

In addition, there are several digitized collections that contain relevant sources. As a result of the ongoing declassification and environmental cleanup of nuclear sites, the DOE[26] maintains two websites which host collections of digitized and declassified sources. The DOE's SciTech Connect website[27] and OpenNet website[28] contain different sets of documents. SciTech Connect, which is more focused on scientific papers and reports, contains material which is useful for understanding the technical aspects of the nuclear facilities as well as the scientific challenges faced in the refinement of uranium.[29] The DOE OpenNet website contains a

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[26] The Department of Energy took over the administration of the Atomic Energy Commission in 1977. As a result, they currently have stewardship of the American nuclear stockpile and the facilities that produced materials for the American nuclear weapons program.

[27] Department of Energy, Office of Scientific and Technical Information: *SciTech Connect*, https://www.osti.gov/scitech/

[28] Department of Energy, Office of Scientific and Technical Information: *OpenNet System*, https://www.osti.gov/opennet/

[29] History Associates Incorporated, "History of the Production Complex: The Methods of Site Selection," 1987, https://www.osti.gov/scitech/servlets/purl/5745137; J. I. Hoffman, "Purification of Uranium Oxide," 1942, https://www.osti.gov/scitech/biblio/4432713-purification-uranium-oxide; P. P. Alexander, "The Production of Uranium Metal by Metal Hydrides Incorporated" (Metal Hydrides Inc., January 1, 1943),

bibliographic reference to every DOE document declassified after 1994, in addition to hundreds of thousands of digitized copies. OpenNet also provides access to the *Manhattan District History*, a text-searchable pdf file, comprised of seven volumes of formerly classified documents and reports summarizing the entire Manhattan Project. It was also through OpenNet that I gained access to a copy of *Linking Legacies*, a 1997 report that details the waste produced from nuclear weapons manufacturing at sites like Fernald.[30]

Finally, this thesis draws from the *Cincinnati Enquirer* and the *Fernald Living History Project*. Articles in the *Enquirer* provide a good overview of the initial public reaction to the construction of Fernald in 1951 as well as the reaction of residents as uranium pollution became publicly known in the 1980s. The *Living History Project* is a series of in-person interviews recorded beginning in 1997 by the Fernald Community Alliance. The project contains over 130 separate interviews with former employees, local residents, and key players in the lawsuits and cleanup operations at Fernald. This source is especially useful because it allows access to the recollections of workers and residents, including their perception of health and environmental risks. Through the oral interviews and newspaper articles, it is clear that certain residents felt angry and frustrated with the Department of Energy after the contamination at Fernald became a national media story in the mid 1980s.[31]

In terms of scope, this study examines the nuclear weapons supply chain which ran from uranium mines in Saskatchewan, Ontario, and the Northwest Territories to Fernald, Ohio. While

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https://doi.org/10.2172/1026498.https://www.osti.gov/scitech/biblio/1026498-production-uranium-metal-metal-hydrides-incorporated.

[30] U.S. Department of Energy, *Linking Legacies*. Unfortunately, these archives contain little documentation between the early 1960s and the early 1980s. There are very few documents dating from after 1963 in any of the archives I searched, especially at the National Archives branch in Atlanta.

[31] Fernald Community Alliance, *Fernald Living History Project*, http://www.fernaldcommunityalliance.org/interviews.html.

previous works focused on the large Los Alamos, Hanford, and Oak Ridge production sites, this thesis concentrates on the Fernald site, which has been neglected by historians. Department of Energy reports suggest that facilities that have received the most scholarly attention –like Hanford– are also the ones that were the heaviest polluters.[32] However, radioactive pollution was prevalent throughout the uranium supply chain, and scholars have begun to explore what possible harms it has caused. For example, David Elijah Bell and Marissa Zappora Bell recently explored the tension between perceived and reported radiological damage in Port Hope, Ontario.[33] Further, Fernald, and to a lesser extent Port Hope, were subject to national news coverage beginning in the late 1980s.[34]

By focusing on the uranium refineries needed to produce atomic weapons, this thesis expands on the environmental themes present in recent scholarship. Uranium was the raw resource needed for every nuclear weapon built in the United States. Tightly controlled by the American government, the vast majority of imported and domestic uranium supplies from 1943 to 1963 were funneled into U.S. atomic weapons production. The complex system of uranium refineries, enrichment plants, and plutonium factories that made weapons production possible irradiated the landscapes and peoples surrounding them. Rooted in the discipline of history, this thesis builds upon current scholarship by examining the Fernald Feed Materials Production Center and exploring the environmental and health consequences of uranium refining.

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[32] U.S. Department of Energy, *Linking Legacies*, 62, table 3-8.
[33] David Elijah Bell and Marissa Zappora Bell, "Port Hope Burning: The Trail of Eldorado, the Uranium Medical Research Centre, and Community Tension over Scientific Uncertainty," in *Nuclear Portraits: Communities, The Environment, and Public Policy*, ed. Laurel Sefton MacDowell (Toronto: University of Toronto Press, 2017).
[34] Kenneth B. Noble, "U.S., for Decades, Let Uranium Leak at Weapon Plant," *The New York Times*, October 15, 1988; Ed Magnuson, "They Lied to Us: Unsafe, Aging U.S. Weapons Plants Are Stirring Fear and Disillusion," *Time*, October 31, 1988; Martin Mittelstaedt, "Town's Residents Test Positive for Uranium Contamination," *The Globe and Mail*, November 13, 2007, https://www.theglobeandmail.com/news/national/towns-residents-test-positive-for-uranium-contamination/article18149068/; Robert Mackenzie, "How Loyalist College Is Helping with a Massive Nuclear Clean Up," *Maclean's*, December 20, 2017, http://www.macleans.ca/education/nuclear-testing-safety-loyalist-college/.

Throughout this thesis, I critically analyze the decisions and actions of the AEC leadership and their industrial contractors and highlight how their decisions contributed to the contamination at the Fernald site.

Chapter 1: The Origins of the Uranium Production Complex, 1942-1952

"…the average person couldn't have imagined digging some raw ore out of somewhere in Africa, …digging it out of the ground, bringing it over here, processing it and ending up with metal uranium at the end product, …and then this metal uranium somehow is going to lead to atomic bombs."[1] Loyd Smith, local resident and former Fernald worker, May 1999

In 1955, Elton Britt recorded "Uranium Fever," a song about leaving his regular day job to adopt the life of a uranium prospector. The song was recorded at the time that the demand for atomic weapons caused uranium to flow from remote mines in Canada and the United States into the heartland of American industry. The American drive for nuclear supremacy during the Cold War necessitated the ability to source and refine large amounts of uranium. As a result, the various agencies and officials responsible for atomic bomb production from the mid-1940s to the mid-1960s constructed and maintained a series of uranium refineries: the first step of the larger nuclear weapons production complex. Not restricted to the United States, the demand for uranium affected Canadian mining companies and successive Canadian governments in addition to the American Army Corps of Engineers and the Atomic Energy Commission. Increasingly determined to produce an atomic bomb, and later to produce an arsenal of weapons, these organizations worked together across an international border to ensure a steady and plentiful supply of uranium. In doing so, however, they ignored reports of environmental damage and sacrificed worker safety. This first chapter analyses the origins of the uranium production system, beginning with the Manhattan Project and ending with the first successful test of a hydrogen bomb in 1952.

[1] Loyd Smith, interview with Fernald Living History Project, May 28, 1999.

The material origins of the world's first nuclear weapons pre-dated the Manhattan Project. There is roughly as much uranium in the earth's crust as there is tin. However, because of the reactivity of uranium, it is rarely found in rich deposits suitable for economic extraction.[2] The uranium ore that eventually became the cores of Little Boy and Fat Man was brought to the surface as a result of the world-wide appetite for radium. At the beginning of the First World War, radium was in high demand and very expensive: roughly $100,000 a gram.[3] With this price point, it was profitable for prospectors and mining companies to seek out pitchblende deposits in remote and difficult to reach locations.[4] Towards the end of the First World War, a radium mine was dug by the Union Minière du Haut Katanga (UMHK) at Shinkolobwe in the Belgian Congo. This was followed by a mine dug by Eldorado Mining and Refining at Port Radium in the Canadian Northwest Territories in 1932.[5] These mines were dug to extract pitchblende, which was then refined for its radium content. While the uranium content of these ores was much higher than the radium content, there was simply no substantial market for uranium, especially one that could be considered profitable from such remote mines. As a result, UMHK and Eldorado focused on radium production, and treated uranium as a by-product.

The combined output of the Port Radium and Shinkolobwe mines lowered radium prices on the global market and encouraged the development of refining capacity for radium ore. UMHK had operated a radium refinery for Shinkolobwe ores since the early 1920s in Olen, Belgium. By 1933, Eldorado had opened a refinery in Port Hope, Ontario. In its first year of operation, the Eldorado refinery produced three grams of radium and 35,000 pounds of various

[2] Charles D. Harrington and Archie E. Ruehle, eds., *Uranium Production Technology* (Princeton: NJ: D. Van Nostrand Company, 1959), 1.
[3] Bothwell, *Eldorado*, 7. All dollar figures from *Eldorado* are contemporary and in U.S. dollars.
[4] Pitchblende is one of many uranium-bearing ores found in the earth's crust. Throughout this thesis, I will refer to uranium ores in general, and pitchblende in particular as a radium-bearing ore.
[5] Bothwell, *Eldorado*, 8-39.

uranium oxides. At the same time as yields increased in Port Hope, global radium prices fell. In 1932, radium traded hands for $70,000 a gram. By 1937, the price had fallen to $25,000 a gram. That same year, Eldorado produced 24 grams of radium. Despite a virtual monopoly on global radium production and the formation of an official cartel to enforce it, the radium refineries at Port Hope and Olen were in danger. By 1939, Eldorado was in financial straits. While Eldorado had great success in finding, developing, mining, and refining pitchblende ore, it was not enough to prevent the closure of Port Radium in 1940. On the other side of the Atlantic, the invasion and swift collapse of Belgium by Nazi Germany in May 1940 removed its production from Allied control.[6]

Fortunately for Eldorado, the same actions which caused the end of Belgian radium production inspired the actions behind the eventual resurrection of Port Radium. Throughout the 1930s, physicists had been busy studying the nature of atomic particles. In particular, they began to turn their attention to whether or not an atom could be split to produce energy. In 1938, Otto Hahn and Fritz Strassmann conducted an experiment that confirmed that the uranium atom could be split by neutrons.[7] Nuclear fission was now a physical reality. The announcement of this scientific advancement set off a flurry of both academic publications and scholarly speculation regarding nuclear fission and its potential use. In particular, émigré scientists living in the United States and the United Kingdom feared that Nazi Germany might be working on an atomic bomb, even as the feasibility of such a weapon was intensely debated. Physicists were sufficiently concerned that within six weeks of Germany's invasion of Poland on September 1, 1939, Leo Szilard wrote a letter to President Roosevelt, signed by Albert Einstein, which urged the United

[6] Bothwell, *Eldorado*, 8-75.
[7] Sherwin, *A World Destroyed*, 14.

States to begin an atomic bomb program, and warned of the possibility of Germany's progress in this field. Soon afterwards, FDR directed members of his administration to create an ad-hoc uranium committee to explore the feasibility of an atomic bomb.[8]

The Uranium Committee achieved little. The next major developments in atomic bomb research came instead from scientists working in the United Kingdom. By April 1940, Otto Frisch and Rudolf Peierls had concluded that major steps towards atom bomb development were theoretically feasible, including a means of detonation, the separation of uranium-235 from uranium-238, and radiation problems that might result from detonation. Most importantly, Peierls and Frisch argued that the amount of uranium-235 required for a bomb was much less than previously thought, perhaps roughly 25 pounds.[9] Their report, known as the Frisch-Peierls Memorandum, was impressive enough to convince the British government to divert increased resources to atomic bomb research.

By the spring of 1941, the British equivalent of the American Uranium Committee had concluded that if enough uranium-235 or plutonium were available, it would be possible to construct an incredibly powerful, yet relatively lightweight, atomic bomb within two years.[10] Known as the MAUD Committee Report, this information did not reach the Americans until July 1941. Once it did, it quickly resulted in changes to the American atomic research effort. In October 1941, the Uranium Committee was replaced with the S-1 Committee –officially "Section-1" of the Office of Scientific Research and Development– staffed with scientists and administrators from the highest levels of government: President of the Carnegie Institution

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[8] Sherwin, *A World Destroyed*, 27-28.
[9] Craig Nelson, *The Age of Radiance: The Epic Rise and Dramatic Fall of the Atomic Era* (New York: Simon & Schuster, 2014), 120–21.
[10] Sherwin, *A World Destroyed,* 34-36.

Vannevar Bush, President of Harvard University James B. Conant, Secretary of War Henry L. Stimson, Chief of Staff General George C. Marshall, and Vice President Henry A. Wallace.[11] In this sense, the idea of an atomic bomb had gone from the most obscure possibility in 1938 to a viable research project overseen by the nation's senior officials in 1941.

For all the excitement that the MAUD Committee report injected into the American research efforts, the S-1 Committee had done little in terms of actually building a bomb. That task fell to General Groves and the Army Corps of Engineers. In March 1942, President Roosevelt approved Bush's recommendation that development should be turned over to the War Department. By October, Conant was confident that the theoretical phase of atomic research was over, and that it was simply a matter of development, solving technical problems, and time.[12] Time, of course, was one resource that the S-1 Committee believed to be in very short supply. Many of the physicists had thus far concluded that it would take approximately two years to build an atomic bomb. If this was the case, then the United States had precious little time to waste, lest the Germans complete a bomb first. By the end of 1942, two major decisions were made with regards to atomic bomb production. First, the S-1 Committee decided to put its resources behind all five viable fission production methods.[13] Second, the U.S. Army Corps of Engineers took control of the administration of atomic bomb production. Commanded by the engineer who had just overseen the construction of the Pentagon, General Leslie Groves, direct Army control of the atomic bomb project marked a shift towards the construction of factories and the production of fissile materials. The Manhattan Project had officially begun.

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[11] Sherwin, *A World Destroyed*, 36–37.
[12] Sherwin, *A World Destroyed*, 38-71.
[13] Richard Rhodes, *The Making of the Atomic Bomb* (New York: Simon & Schuster, 1986), 406.

Despite the rapid developments in atomic research, the companies which were mining, refining, and ultimately using radium and uranium had had relatively little contact with the American bomb project. Although the *New York Times* announced the discovery of nuclear fission in February of 1939,[14] the radium companies were pre-occupied with falling profits and a looming international crisis. Indeed, the beginning of the Second World War proved disastrous for Eldorado and Union Minière. In Eldorado's case, the announcement of war in 1939 and the success of Hitler's armies in 1940 removed many customers in continental Europe from the market place and ensured that what customers remained in Canada and the UK had turned their resources to a total war economy. Profits dramatically fell from 1938 to 1940.[15] For UMHK, the closure of their refinery should have been the end of their business. However, UMHK had the foresight to ship stocks of uranium compounds to ports in the United States and Great Britain before the outbreak of hostilities. For Eldorado too, the problem was not a lack of materials. Executives estimated they had enough uranium ore in 1940 to cover sales for the next five years and subsequently chose to shut down the mine at Port Radium.[16] It seemed as if there was an over-supply of uranium at the beginning of the Second World War.

To actually construct atomic bombs, however, required a completely new scale of production. To the radium companies, uranium was essentially a waste product. It was many times more plentiful than radium in the ores that they mined, but prior to the war the market was extremely limited. The only reliable customers of uranium oxides prior to the Second World War were ceramics companies, who consumed roughly 150 tons of uranium oxides per year in the United States.[17] Whereas companies sold radium by the gram and microgram, the engineers and

[14] "Revolution in Physics," *New York Times*, February 3, 1939.
[15] Bothwell, *Eldorado*, 73.
[16] Bothwell, *Eldorado*, 76.
[17] *Manhattan District History*, Book VII, Volume 1, Feed Materials and Special Procurement, sec. S8.

scientists of the Manhattan Project decided that they would need about 1,700 tons of uranium oxide (U_3O_8) by the middle of 1944 to build a bomb. In other words, the Army Corps of Engineers would need to, in a period of two years, produce eleven times as much uranium oxide as the industry typically used in a year. For this reason, they wasted little time in procuring uranium where the capacity already existed. In March 1942, the United States placed the first large order for uranium oxide from Eldorado: 60 tons. While this order alone was enough to justify the re-opening of the Port Radium mine, the orders continued.[18] On July 16, the Manhattan Project ordered 350 tons of uranium oxide at $2.05 per pound. Four months later, they ordered another 500 tons to be delivered by the end of 1944. These orders not only monopolized the production of uranium by Eldorado to the Manhattan Project but also proved problematic. Eldorado's refinery at Port Hope was only capable of producing 150-200 tons of oxide each year.[19] While Eldorado worked to upgrade their refinery and meet their contracts, the Manhattan Project turned to American refineries to pick up the slack.

In the world of uranium refining during the Manhattan Project, the basic unit of uranium was black oxide (U_3O_8). It was from this oxide that all other uranium products were refined and provided a consistent measurement in terms of supply. Whereas uranium ores could vary wildly in their purity, and the reduction of uranium oxides to metal could be more or less efficient, the amount of uranium in black oxide remained constant. In 1942, there were only two facilities in North America which could refine uranium ore into black oxide: the Eldorado refinery, and the Vitro Manufacturing Company refinery in Canonsburg, Pennsylvania.[20] Like the Eldorado refinery, the Vitro refinery was originally constructed to refine radium from uranium ores.

[18] Bothwell, *Eldorado*, 97–98.
[19] Bothwell, *Eldorado*, 109–12.
[20] *Manhattan District History*, Book VII, Volume 1, Feed Materials and Special Procurement, sec. 1.10.

Sometime prior to the beginning of the Manhattan Project, the Vitro refinery began to specialize in uranium products, and produced black oxide and sodium uranate ($Na_2U_2O_7$). However, compared to the Eldorado refinery, the Vitro refinery was quite small. While Eldorado was eventually able to process 225 tons of uranium ore per month, Vitro was designed to accept only 40 tons a month. In addition, the Vitro and Eldorado refineries were more efficient when they used high-grade ores of 50 and 20 percent, respectively.[21] As a result, the Manhattan Project decided to construct a new plant that could efficiently refine low-grade uranium ores. Under a cost plus fixed fee contract, the Linde Air Products Company constructed a three-step uranium refinery in Tonawanda, New York. Completed in July 1943, the Linde refinery converted uranium ore into black oxide, then brown oxide (UO_2), and finally green salt (UF_4).[22]

Until Linde could come online, however, the administrators of the Manhattan Project still needed additional refining capacity. While Eldorado and Vitro could produce black oxide and sodium salt, these materials still needed to be further refined to be useful for nuclear fission. In late 1942, the Manhattan Project contracted the Mallinckrodt Chemical Works (MCW) to construct, at their own expense and as their own property, a uranium refinery at their existing chemical works in St. Louis, Missouri. Rather than converting raw ore into black oxide, however, MCW accepted the black oxide and sodium salt from Eldorado and Vitro and converted it into brown oxide.[23] Further, MCW also constructed, for a lump-sum fee, a green salt (UF_4) and uranium metal plant on adjacent lands rented from the St. Louis Sash and Door Works.[24] In addition to the complex in St. Louis, Manhattan Project administrators contracted the DuPont company to construct a similar uranium refinery at the pre-existing DuPont Chambers

[21] *Manhattan District History*, Book VII, Volume 1, Feed Materials and Special Procurement, sec. 7.1.
[22] *Manhattan District History*, Book VII, Volume 1, Feed Materials and Special Procurement, sec. 7.7.
[23] *Manhattan District History*, Book VII, Volume 1, Feed Materials and Special Procurement, secs. 8.1-8.3.
[24] *Manhattan District History*, Book VII, Volume 1, Feed Materials and Special Procurement, secs. 9.1-9.2.

Works in Deepwater, New Jersey. The DuPont refinery was similar to Linde and MCW in that it produced green salt from black oxide, but it differed in that it also contained a scrap recovery plant. Beyond this difference, however, the Linde, MCW, and DuPont refineries operated using similar processes and produced roughly identical products.

By the summer of 1943, the brown oxide/green salt plants were in operation. Green salt was a useful intermediate product that could be further processed to produce either pure uranium metal or uranium hexafluoride (UF_6).[25] By the summer of 1943, there were four uranium metal plants in operation in the United States: the two plants at Deepwater and St. Louis, as well as the Electro Metallurgical Company plant in Niagara Falls, New York, and a metal plant at Iowa State University in Ames, Iowa. While various methods of uranium metal production were researched, the most effective method was to reduce green salt with powdered magnesium to produce pure uranium metal. This metal was then fed into the X-10 pilot reactor at Oak Ridge and later the massive production reactors at the Hanford Engineer Works. The reactors irradiated uranium slugs in order to transmute a small fraction of the uranium into plutonium. The irradiated slugs were then dissolved in acid to separate the plutonium from the other elements present. The final product was a plutonium nitrate solution which was sent to Los Alamos under heavy guard.[26]

While there were multiple plants for converting green salt into metal, there was only a single plant that the Manhattan Project contracted for the production of uranium hexafluoride. The Harshaw Chemical Company's Brooklyn Works in Cleveland, Ohio contained both a green salt plant and a hexafluoride plant by 1944. The hexafluoride plant's position within the

[25] Uranium metal would eventually be used to produce plutonium, while uranium hexafluoride was used in gaseous diffusion plants to produce enriched uranium.
[26] *Manhattan District History*, Book I, Volume 14, Intelligence and Security, Top Secret Appendix to Supplement.

production system was rather important. By 1942, Manhattan Project scientists had deduced that the quickest way to produce large amounts of enriched uranium involved the construction of enormous facilities to physically separate the fissile uranium 235 isotope from the more plentiful, but non-fissile uranium 238 isotope.[27] To facilitate the physical separation of these isotopes, brown oxide had to be converted into a gaseous compound. Uranium hexafluoride is a solid at room temperature but quickly sublimes into a gas at elevated temperatures. Uranium hexafluoride is also quite reactive, and incredibly toxic. Despite these challenges, Harshaw produced over 1,600 tons of hexafluoride for the mammoth enrichment plants at Oak Ridge by 1947.[28]

In a certain sense, the efforts by the Manhattan Project were quite successful. The feed materials program had procured over 10,000 tons of U_3O_8 and produced 6,600 tons of pure uranium by the beginning of 1947. This amount of uranium, the official *Manhattan District History* proudly claims, is an amount that was greater than the total quantity of uranium produced in the world prior to the beginning of the Manhattan Project.[29] Through the construction and operation of the uranium plants, the Manhattan Project effectively created a new industry. This industry mined a relatively obscure substance in remote locations and transported it to be refined in the center of the American industrial landscape. Those refined products then continued on to become the fuel that powered the world's first atomic weapons. Especially when one considers the original goal of 1,700 tons of uranium oxide, the feed materials program completed incredibly successful work in a short period of time. But this

[27] Rhodes, *The Making of the Atomic Bomb*, 406–7.
[28] *Manhattan District History*, Book VII, Volume 1: Feed Materials and Special Procurement, Appendix "D," Graph D-11.
[29] *Manhattan District History*, Book VII, Volume 1: Feed Materials and Special Procurement, sec. 1.1.

success had a price, both in the financial and environmental sense. By 1 January 1947,[30] the feed materials program of the Manhattan Project had spent over $90,000,000 to procure and refine uranium products. Of this figure, nearly $59,000,000 was spent operating the various refineries simultaneously.[31] While this strategy did have the advantage of rapidly increasing production capacity, it also spread radioactive wastes to more landscapes and workers than a single uranium refinery would have.

In a 1948 memo to his superior, A.E. Gorman, a sanitary engineer with the Atomic Energy Commission stated that "The A.E.C., like most rapidly expanding industrial organizations, such as, steel, coal, by-product coke, rubber, oil refining, tanneries, sulphite pulp, canning, creameries, etc., has found that its operations create serious problems for and affect the rights of others in the area of these operations."[32] The uranium refineries, like other industries across the United States, heavily polluted the surrounding environments. Through the operation of a uranium refinery, the toxic and radioactive compounds were dumped or otherwise leeched into the ground, water, and air surrounding these factories. In line with common industrial practice at the time, waste products from uranium refining were deposited into nearby lakes, streams, waste grounds, and the surrounding air.

Where the refineries differed from other industries, however, was the addition of radioactivity into the environment. Unlike other noxious pollutants, radioactivity is undetectable by human perception. Its ability to silently destroy human tissue has inspired fear and fascination

[30] On this date, the Atomic Energy Commission (AEC) legally took over the administration of atomic bomb production in the United States. For this reason, the end of the Manhattan Project in 1947, rather than the end of the Second World War, separates many statistics.
[31] *Manhattan District History,* Book VII, Volume 1: Feed Materials and Special Procurement, sec. S4. Figures in 1947 dollars.
[32] A.E. Gorman. Memo to Roger S. Warner, Jr., "Cooperation with Other Federal Agencies in Problems of Waste Disposal, Water Supply, and Environmental Hazards," February 9, 1948, Box 2, Series 7, Record Group 326, NARA, Atlanta.

for decades. The nuclear weapons production system was the world's first industry to issue large amounts of radioactive particles into the surrounding environment. At the time, scientists had very little understanding about the long-term consequences of radioactive contamination. By 1950, several soil and water surveys conducted at various Manhattan Project sites revealed levels of uranium clearly elevated from the background level.[33] Within the perimeter of the Harshaw facility, tests showed that the uranium level in the soil was anywhere from 190 to 340 parts per million (ppm).[34] In addition, the report clearly stated that uranium refining at AEC facilities was adding radioactivity to the streams that drained into larger bodies of water. In a particularly alarming example, the same report states that surface water downstream from a scrap storage facility in St. Louis, Missouri, was found to contain eighteen times the limit for uranium concentration in water as defined by the National Bureau of Standards.[35] Despite these clear findings of radioactive pollution, scientists were unsure about what the long-term consequences might be, and whether or not these levels actually posed a public health threat. This attitude continued into the 1980s, where DOE and EPA officials repeatedly claimed that radioactive contamination at various DOE sites posed no danger to the public as national newspapers ran headlines highlighting decades of contamination.

In addition to local pollution at the refineries, pollutants tended not to stay within the facility boundaries. While natural forces like wind and rain moved some contaminants beyond factory fences, human hands moved far more contaminants between facilities. Not only were uranium compounds moving from one facility to the next in the production chain, scrap products

[33] D.E. Lynch, "Soil and Water Uranium and Radium Survey Progress Report," June 20, 1950, Box 2, Series 27, Record Group 326, NARA, Atlanta. The report stated that normal background uranium levels in the soil varied from 3 parts per million to 9 parts per million.
[34] Lynch, "Soil and Water Uranium and Radium Survey Progress Report," 37.
[35] Lynch, "Soil and Water Uranium and Radium Survey Progress Report," 27.

were as well. The nature of uranium refining in the 1940s was such that there was a large amount of uranium left over in the residues from the refining process. Often, there was a higher percentage of uranium in the scrap materials than in the fresh uranium ore being mined elsewhere. However, it was uneconomical to process the scrap material repeatedly only to get diminishing returns. In the race to build the first atomic bomb, the most expedient methods were preferred, and the scrap material inventory grew. Sometime after 1945, engineers began shipping uranium scrap to a centralized location at a former explosives factory about fifteen kilometers north of Niagara Falls on the shores of Lake Ontario. The Lake Ontario Ordinance Works (LOOW) became one of the major repositories for uranium scrap in the 1940s.

It did not take long before large amounts of uranium scrap began to pile up at LOOW. By October 1948, LOOW held over 19 million pounds of various types of uranium-bearing sludge, residues, and precipitates. Containing only the equivalent of 60,000 pounds of uranium metal, this material was stored in concrete buildings, in steel drums, or simply dumped onto the bare ground.[36] Even with this ad-hoc approach, there was insufficient space to store the increasing levels of scrap from the rest of the production system. Eventually, administrators decided to construct a storage silo for a particularly useful scrap residue known as K-65. Shipping and storing large amounts of scrap or waste to LOOW, however, presented challenges. AEC administrators had primarily selected LOOW to store uranium scrap based on convenience, rather than any particular quality that might have made storage secure or easy.[37] The facility

[36] "Survey of Accounting Control over Source and Fissionable Materials," October 9, 1948, Box 4, Series 27, Record Group 326, NARA, Atlanta.
[37] S.R. Sapirie, Letter to Joe W. Howland, "Waste Disposal at the University of Rochester Atomic Energy Project," January 31, 1956, Box 8, Series 27, Record Group 326, NARA, Atlanta.

lacked loading and unloading facilities, which, in turn, forced workers to come into prolonged contact with radioactive uranium scrap in the course of normal operations.

On December 2, 1949, African Metals Corporation (AMC) agreed to pay for the extra labour required to ship uranium scrap (to which they retained ownership, despite its use in nuclear weapons production).[38] As part of the deal, AMC also agreed to pay for the medical examinations of the shipping contractor's proposed employees. Engineers at the AEC were becoming worried about radiation exposure in workers at LOOW. In November 1950, industrial hygienist Richard Heatherton issued a report that confirmed these fears. Heatherton found that the average worker dumping scrap uranium at LOOW could expect to receive 435 millireps every week.[39] This level of exposure was nearly one and a half times the limit for workers in the Atomic Energy Commission in 1950, and four and a half times the current limit for nuclear workers in the United States. Heatherton suggested several ways to reduce the exposure of radiation, including the installation of better safety equipment, and the hiring of additional workers. He noted, for example, that operators had installed a concrete shield to protect workers when they were removing the lids from the drums containing uranium scrap. However, use of the shield required a machine to remotely open the lids which had not been installed.[40] Fifty years later in an interview with *USA Today*, Heatherton admitted that for the AEC and their contractors, production was the priority. While the AEC recognized the risks, and eventually

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[38] Phillip L. Merritt to M.M. Bowman, "Storage of Sludge," December 5, 1949, Box 7, Series 27, Record Group 326, NARA, Atlanta.
[39] Heatherton, "Radiation, Radon, and Dust Survey." The Roentgen equivalent physical (rep) is an obsolete unit of absorbed radiation dose.
[40] Heatherton, "Radiation, Radon, and Dust Survey."

installed safety equipment, Heatherton explained that the production of nuclear weapons components always came before environmental and health concerns.[41]

Increasing demand for uranium and its related fissile products after the Second World War did not equate to an increased demand for more uranium refineries. Most of the refineries that made up the nuclear weapons production complex during the Manhattan Project would not survive to see the end of the 1940s. Budgets that were justified in the minds of the American electorate as necessary to beat Nazi Germany in the race to an atomic bomb were no longer sustainable after the end of the Second World War. President Harry Truman was, after the surrender of Japan in August 1945, under great pressure to reduce military spending. The uranium refineries, especially those that were older and less efficient, were particularly vulnerable to spending cuts. By the end of July 1946, the refineries at the DuPont Deepwater Works, Linde, Iowa State, and Electro Metallurgical Company had been shut down. In their place, the American government decided to centralize uranium production and increase the capacity of the Mallinckrodt Chemical Works refinery. The best data at the time told Manhattan Project engineers that MCW was delivering the highest purity product at the cheapest price. In order to stretch limited uranium supplies as far as they could go, they made the decision to expand MCW and sacrifice the security and redundancy of multiple uranium refineries.[42]

Despite Truman's budget cuts, the demand for nuclear weapons grew after the Second World War. Upon hearing news of Japan's surrender in August of 1945, many Manhattan Project scientists assumed that atomic bomb production would cease. The United States had spent an incredible amount of money to produce just three weapons by the end of the war. The American

[41] Eisler, "Toxic Exposure Kept Secret."
[42] *Manhattan District History*, Book VII, Volume 1, Feed Materials and Special Procurement. Sec. 8 to 10.

military leadership, however, thought differently. The ink on the Japanese Articles of Surrender had scarcely dried by the time General Lauris Norstad wrote to General Groves on 15 September 1945. Agonizing over the large number of conventional Soviet forces, Nortstad argued that the United States Army Air Forces (USAAF) required a minimum of 123 atomic bombs, and ideally a stockpile of 466 weapons, to completely defeat the Soviet Union.[43] While Groves thought this estimate was quite high, he did agree that the United States should increase its stockpile of atomic bombs.[44] In direct opposition to some atomic scientists, military and political leaders favoured increased bomb production and came to rely on them to shift the balance of power in a time of rapid American demobilization. As General Nortstad's estimates show, however, stockpile requirements from the military were not even remotely based on the AEC's ability to manufacture weapons. Instead, the ever-increasing stockpile requirements seemed to be justified based on how many targets the military could find, rather than how many bombs the United States could build. The gap between perceptions of the bomb's power and the actual size of the stockpile was so great among the American military and civilian leadership that when AEC chairman David Lilienthal briefed President Truman in 1947, the President was shocked to discover that the United States only possessed roughly seventeen working bombs.[45]

Despite the difference between the imagined might of the American nuclear monopoly and the actual strategic situation, bomb development and production continued. On the international stage, several events occurred between 1945 and 1950 that encouraged the United States to procure a larger arsenal of nuclear weapons. The Truman administration saw crises in

[43] Gordin, *Red Cloud At Dawn*, 27.
[44] "The First Atomic Stockpile Requirements (September 1945)," *Restricted Data: The Nuclear Secrecy Blog* (blog), http://blog.nuclearsecrecy.com/2012/05/09/weekly-document-the-first-atomic-stockpile-requirements-september-1945/.
[45] Herken, *The Winning Weapon*, xiii and 187.

Greece and the Turkish Straits in 1946 and 1947 as direct threats to the postwar strategic balance. The beginning of the Berlin Blockade in 1948 was further evidence to the American leaders that the Soviet Union was inherently aggressive, and that concrete steps needed to be taken by the United States to contain them. Truman retaliated to these perceived threats by announcing American support for the governments of Turkey and Greece, the Berlin Airlift, and later by organizing the formation of NATO in April 1949. Four months later in August 1949, the Soviet Union detonated its first atomic bomb. This came as a complete shock to the American leadership, who had assumed that the Soviets were still many years away from producing a bomb. In April 1950, National Security Council Paper 68 (NSC-68) was adopted as formal policy, a policy that committed the United States to contain the Soviet Union and prevent the spread of communism throughout the world. By June, American troops were directly engaged with North Korean soldiers in a war that would last three years and result in very little territory lost or gained. In these five short years, the Grand Alliance formed between the United States, the Soviet Union, and the United Kingdom during the Second World War had dramatically devolved into an openly hostile relationship between two nuclear-armed superpowers.[46]

The newly created AEC worked to grow the nuclear stockpile in response to rising tensions and military demands for weapons. Since the AEC was a civilian agency, it was supposed to create distance between the military leadership and the production of powerful atomic weapons. Still, the military had overseen the Manhattan Project and they retained intimate connections to the leadership of the AEC and the President. In order to answer calls for more weapons to shore up the American strategic position, AEC commissioners proposed a program of geologic surveys to find additional deposits of uranium. The uranium being mined

[46] Martin McCauley, *Origins of the Cold War: 1941-1949* (London: Pearson Longman, 2008).

from Port Radium and Shinkolobwe, while abundant, was not enough to satiate American generals. In 1948, the AEC began a program to encourage private development of American uranium deposits. The program contained incentives for private enterprise that included minimum prices for uranium ores and bonuses for the discovery of new deposits.[47] On the Canadian side of the border that same year, the Liberal government announced a similar program which allowed private prospectors to look for uranium across Canada.[48] Despite these programs, it would take time to discover major deposits and even longer to bring new uranium mines into production. By the time the Korean War erupted in 1950, geologists had located major deposits in the western United States, northern Saskatchewan, and in Ontario. The domestic American deposits, however, were very low-grade. As a result, the AEC focused on improving the production system in anticipation of increased uranium supplies.

On November 1, 1952, the United States detonated the world's first thermonuclear device on the island of Enewetak in the Marshall Islands. Code-named Ivy Mike, the test produced an explosion over 500 times as powerful as the Fat Man explosion over Nagasaki only seven years earlier. As the first successful test of a thermonuclear design, Ivy Mike signaled the beginning of a new nuclear arms race. Uranium powered this race and determined everything from the number of bombs that could be built to their explosive potential. As a result, the facilities that processed and purified the atomic fuel were incredibly important to the larger atomic program. In anticipation of both increased uranium receipts and ever-larger stockpile requirements from the nation's military leadership, the AEC developed a modernization and expansion program that drastically increased the nation's ability to refine and produce uranium products.

[47]David E. Lilienthal et al., "Fourth Semiannual Report to the Congress by the United States Atomic Energy Commission, July 1948" (U.S. Atomic Energy Commission, Washington, DC, July 1, 1948), 49.
[48] Bothwell, *Eldorado*, 246–47.

The efforts to refine uranium in support of the Manhattan Project transformed the preceding radium industry and created a supply chain that stretched from the Congolese jungle and the Canadian subarctic to the New Mexican desert. This chapter has argued that the temporary, decentralized uranium production system created during the war was subject to military pressures and a race to produce as much uranium as possible in the shortest amount of time. Although American officials quickly understood that their uranium refineries were polluting the surrounding environment and worker's bodies, the ultimate goal of production remained as the strategic wartime priority. The next phase of uranium refining in the United States was, in some ways, different. The next generation of uranium refineries were larger and were constructed to last longer than the ad-hoc facilities of the Second World War. These new facilities were designed to be more efficient and to handle larger amounts of uranium than their predecessors did. However, the new facilities also inherited the precedent established by the Manhattan Project. Faced with the pressures of the Cold War, the new generation of uranium refineries adopted a similar prioritization of production at the expense of high environmental pollution. The next chapter will explore the implications of developing a centralized production system by examining the Fernald Feed Materials Production Center, a uranium refinery established near Cincinnati, Ohio.

Chapter 2: The Expansion of the Uranium Production Complex, 1950-1957

"The A.E.C. … has found that its operations create serious problems for and affect the rights of others in the area of these operations."[1] A.E. Gorman, AEC sanitary engineer, February 1948

At dawn on Sunday, 25 June 1950, North Korean soldiers crossed the 38th parallel into the Republic of Korea, sparking the first major military confrontation of the Cold War. Over the next three years, American forces suffered multiple setbacks against North Korean and Chinese troops. Frustrated at the lack of progress, generals began to advocate for the deployment of nuclear weapons to reverse American failures. Truman's response to such suggestions was complicated. Firmly believing in presidential authority over the use of nuclear weapons, he fired General MacArthur in 1951 when the latter threatened to undermine presidential authority. At roughly the same time, he ordered the Atomic Energy Commission to release nuclear components into the hands of the military.[2] The Korean War ended before the United States deployed nuclear weapons, but it served as a dramatic opening to a decade filled with significant developments in American nuclear history.

Fueled by Cold War tensions and an eager military leadership, the Atomic Energy Commission (AEC) was under constant pressure to produce ever-larger amounts of nuclear weapons. In Truman's final years as president, he authorized large budget increases to the agency. The AEC used these funds to shut down old uranium plants and to build new ones. New uranium refineries at Fernald (1954) and Weldon Spring (1958) enabled the AEC to refine

[1] A.E. Gorman, Memo to Roger S. Warner, Jr., "Cooperation with Other Federal Agencies in Problems of Waste Disposal, Water Supply, and Environmental Hazards," February 9, 1948, Box 2, Series 7, Record Group 326, NARA, Atlanta.
[2] Richard G. Hewlett and Francis Duncan, *A History of the United States Atomic Energy Commission, Volume 2: Atomic Shield, 1947-1952* (University Park, PA: Pennsylvania State University Press, 1969), 539. Also see Rosemary Foot, *The Wrong War: American Policy and the Dimensions of the Korean Conflict, 1950-1953* (Ithaca: Cornell University Press, 1985).

growing amounts of uranium in a more centralized fashion. Combined with a drastic increase in the raw uranium supply after 1955, the Commission vastly improved its ability to manufacture nuclear weapons. In doing so, however, the AEC knowingly contaminated the Ohio countryside and local workers inside the Fernald Feed Materials Production Center.

Even before the outbreak of hostilities on the Korean peninsula, the AEC was planning for an expansion based on the larger effort to develop the hydrogen, or thermonuclear, bomb. On 31 January 1950, following a strenuous debate among both atomic scientists and national policy makers that began during the Manhattan Project, President Truman announced that the United States would accelerate the effort to produce such a bomb. Once Truman made the declaration, it fell to the AEC to manufacture the required materials. However, there was a significant disagreement as to the most efficient way to manufacture these nuclear weapons. In the run-up to Truman's declaration, the Joint Chiefs of Staff believed that building fewer H-bombs would be more efficient than using the same fissile material to manufacture many more A-bombs.[3] Paul Fine, a member of the AEC's military application division, countered with his own findings. Fine argued that to produce enough tritium for a single prototype thermonuclear bomb required a facilities expansion worth $150 million and significant quantities of uranium that could otherwise be used to build fission bombs.[4] William Golden, an aid to AEC Chairman Lewis Strauss, came to a different conclusion. In a letter written in the immediate aftermath of the first Soviet nuclear detonation in 1949, Golden argued that the United States should intensify its efforts towards the development of "superweapons". He went on to argue that the development of hydrogen bombs was much more important than an increase in the rate of production of

[3] In the 1950s, thermonuclear weapons were known by several names. Scientists often referred to them as "Super" bombs before they were successfully tested. The media often referred to them as "H-Bombs", and then later as fusion or thermonuclear weapons.
[4] Hewlett and Duncan, *Atomic Shield,* 395, 397.

existing weapons.[5] As a result, the AEC faced a problem: it simply did not have the uranium supply and production facilities to fulfil the twin directives of increasing fission bomb production and accelerated work on the hydrogen bomb at the same time.

The answer to this problem was an expansion program. However, AEC administrators were unsure of how large an expansion was necessary. In the first half of 1950, a thermonuclear weapon was still in the stage of experimental speculation. Scientists had not produced a working prototype, and there was significant disagreement over whether such a bomb was physically possible. While the AEC was confident that the Hanford Site could manufacture enough tritium for a single test within a year, this would not suffice for full-scale production. On 8 June 1950, Truman authorized the construction of two new heavy-water reactors for tritium production.[6] The construction of the new reactors were in addition to expansions that were already under way at Hanford and Oak Ridge by the summer of 1950.[7] These expansions would increase the United States' ability to convert refined uranium into plutonium and enriched uranium. However, expanded facilities at Hanford and Oak Ridge did nothing to improve the supply of refined uranium. In 1949, the AEC's uranium supply was tenuous, with 84 percent of its uranium coming from foreign sources. Until 1955, much of the uranium for the American bomb program came from the Shinkolobwe mine in the Belgian Congo. The effort to produce an H-bomb would make that supply even more vulnerable by reducing the amount of uranium available for plutonium production.[8] By the summer of 1951, however, the AEC was confident that the newly discovered uranium deposits in Canada would drastically change their supply situation within a

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[5] Richard Rhodes, *Dark Sun: The Making of the Hydrogen Bomb* (New York: Simon & Schuster, 1995), 378.
[6] Hewlett and Duncan, *Atomic Shield,* 430.
[7] Hewlett and Duncan, *Atomic Shield,* 473.
[8] Rhodes, *Dark Sun,* 380. For every kilogram of tritium that the United States produced, the key ingredient for an H-bomb, physicists estimated that the AEC would lose enough plutonium for 30-40 atomic bombs.

few years.[9] The expected increase in uranium supply, coupled with the increased production demands, meant that the AEC would have to plan for yet another expansion to refine uranium and feed the other production plants.

At the same time that the AEC was planning to construct additional reactors, the nation's capacity to produce refined uranium products faced challenges. In the wake of the Second World War, uranium ore supplies to the United States remained relatively low. In order to ensure the efficient use of a scarce resource, the AEC consolidated refining operations at the Mallinckrodt Chemical Works (MCW) in downtown St. Louis. While MCW was the largest uranium refinery at the AEC's disposal, it had several deficiencies. As opposed to the remote –and thus secure– facilities constructed from scratch during the war, MCW was located in the middle of a major industrial city. Further, MCW was not a single building, but rather a series of factories spread out across several city blocks. As a result, MCW was a relatively unsecure facility as compared to Hanford or Oak Ridge. In addition, its location amplified the potential harm to residents and the environment. Without a buffer zone of empty space,[10] contamination from potential accidents, as well as routine operations, negatively affected a larger population. Boxed in by the Mississippi River on one side, and existing infrastructure on the other three, MCW was also unable to expand operations without significant financial investment. As the Joint Chiefs and members of Congress demanded larger and larger fissile materials production, MCW seemed incapable of meeting the growing national defense mission.[11]

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[9] Hewlett and Duncan, *Atomic Shield,* 482.

[10] Here I use the term "empty space" as sanitary engineers saw it. The space, of course, was not empty but it was less densely populated than the industrial portion of a major city. See Brown, *Plutopia*, 59.

[11] This was certainly the case by 1955. In a letter from the AEC area manager for St. Louis to the manager at Oak Ridge, AEC officials complained that the MCW plant in St. Louis was "inadequate and seriously overcrowded." The AEC estimated that it would cost between $1.5 million to $2.5 million to adequately renovate the MCW works in downtown St. Louis. Unfortunately, the archival sources are not clear about whether they were overcrowded from an efficiency standpoint or from a safety perspective. See F.H. Belcher to S.R. Sapirie, "Request for Directive on

The AEC perceived other facilities in a similar light. In January 1949, Edward Sargent, manager of the Ohio area office of the AEC, authored a classified report that argued conditions at the Middlesex Sampling Plant in Middlesex, New Jersey were "…unsatisfactory from both an operational and a health standpoint." Sargent suggested that an investment of about $270,000 was enough to improve the plant, whereas it required roughly $750,000 to build an entirely new plant at a more central location.[12] Despite Sargent's recommendation, the AEC decided to incorporate the functions of the Middlesex plant into the Fernald Feed Materials Production Center, which began full operations in 1954. Closing soon after, the fate of the Middlesex plant was typical of many facilities from the Manhattan Project. Jury-rigged to help refine uranium, the AEC chose to build new plants in centralized locations rather than spend smaller sums to renovate the network of older factories.

A combination of crowded uranium refineries and increasing weapons requirements encouraged unprecedented budgets for the AEC. In the wake of the invasion of South Korea, President Truman twice asked Congress for additional funding for atomic weapons production. On 7 July 1950, he asked for $260 million. On 1 December, he asked for over $1 billion in additional funding to produce fissile materials, much of it earmarked for construction.[13] By the summer of 1951, construction crews were active at three new sites across the country, including Fernald. In order to directly increase plutonium production capacity, a new facility analogous to Hanford was under construction in South Carolina, about 40 kilometers southeast of Augusta, Georgia. In addition, a new gaseous diffusion plant was being built at Paducah, Kentucky. These

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Process Development Facilities for the Weldon Spring Site," January 21, 1955, Box 12, Series 27, Record Group 326, NARA, Atlanta.

[12] E.C. Sargent, "The Practicality of Installing the Middlesex Operations At A New Location" January 19, 1949, Box 6, Series 27, Record Group 326, NARA, Atlanta.

[13] Stephen Schwartz, ed., *Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons Since 1940* (Washington, D.C.: Brookings Institution Press, 1998), 66.

new plants were built in addition to expansions taking place at previously established sites such as Hanford and Oak Ridge. At Hanford, new reactors and processing plants were added to the WWII-vintage facilities. At Oak Ridge, additional capacity to enrich uranium was built. By the time the belligerents on the Korean peninsula called a truce in 1953, the AEC employed nearly 149,000 people across construction sites, production plants, laboratories, and offices in the United States.[14]

At the beginning of 1953, President Eisenhower took office, bringing with him a different conception of what role nuclear weapons should play in the larger context of national defense. His predecessor, President Truman, was quite clear that atomic weapons were special weapons that posed a significant risk to international stability, whether they were used or not. Truman's efforts to place nuclear weapons under the control of a civilian agency, the AEC, and his desire to keep the power to use nuclear weapons within the discretion of the office of the president reflected a well-placed uneasiness regarding the power of nuclear weapons.[15] Eisenhower, by comparison, was eager to change the way nuclear weapons were understood. While Eisenhower spent much of his presidency attempting to push forward arms control agreements, he also spoke about the atomic bomb as just another weapon in the American arsenal.[16]

By the end of 1953, a program of massive retaliation and engagement with the nuclear arms race were major components of Eisenhower's foreign policy. NSC 162/2, approved by Eisenhower in October, outlined the security requirements of the United States in the face of the

[14] Schwartz, *Atomic Audit,* 356.
[15] McGeorge Bundy, *Danger and Survival : Choices about the Bomb in the First Fifty Years* (New York: Vintage Books, 1990). Despite Truman's anxiety about the bomb, he did little during his presidency to prevent the beginning of the nuclear arms race.
[16] See Saki Dockrill, *Eisenhower's New-Look National Security Policy, 1953-61* (London: Palgrave Macmillan, 1996).

Soviet threat. In particular, NSC 162/2 called for "a strong military posture, with emphasis on the capacity of inflicting massive retaliatory damage by offensive striking power." As the document went on to argue, "…sufficient atomic weapons and effective means of delivery are indispensable for U.S. security."[17] Demonstrating a paradigm shift in atomic strategy, NSC 162/2 argued that the same special weapons that Truman had placed under civilian command should become the very cornerstone of American national security. Known to historians as Eisenhower's "New Look" strategy, the reliance on nuclear weapons for national defense quickly ran into trouble. As H.W. Brands notes, the New Look suffered from repeated policy revisions as well as confusion regarding the applicability of using nuclear weapons during the crises in the Taiwan Strait and the conflict in French Indochina.[18]

The New Look relied on a radical advancement in nuclear weapons technology. Despite the significant power of the Ivy Mike test in November 1952, the device weighed 82 tons, and was thus not deployable by any practical means in the American arsenal. Less than two years later in March 1954, the scientists returned with a new design. Detonating a device weighing only 11 tons over the Bikini Atoll, the Castle Bravo test resulted in a 15-megaton explosion.[19] Armed with the knowledge of the successful test, the AEC began to build a new nuclear arsenal. The successful Castle Bravo design was both deployable and had the ability to be mass-produced. In addition, the design was infinitely scalable, meaning weapons designers could make the design larger or smaller with little effort. This development in nuclear weapons design made the American military's wish for an increased variety of nuclear weapons easier to fulfil. As the

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[17] "A Report to the National Security Council," October 30, 1953. Hereafter "NSC 162/2". Federation of American Scientists Intelligence Resource Program, https://fas.org/irp/.
[18]H. W. Brands, "The Age of Vulnerability: Eisenhower and the National Insecurity State," *The American Historical Review* 94, no. 4 (1989): 963–89.
[19] For an analysis of the environmental and health consequences of nuclear testing in the Pacific, see Smith-Norris, *Domination and Resistance*.

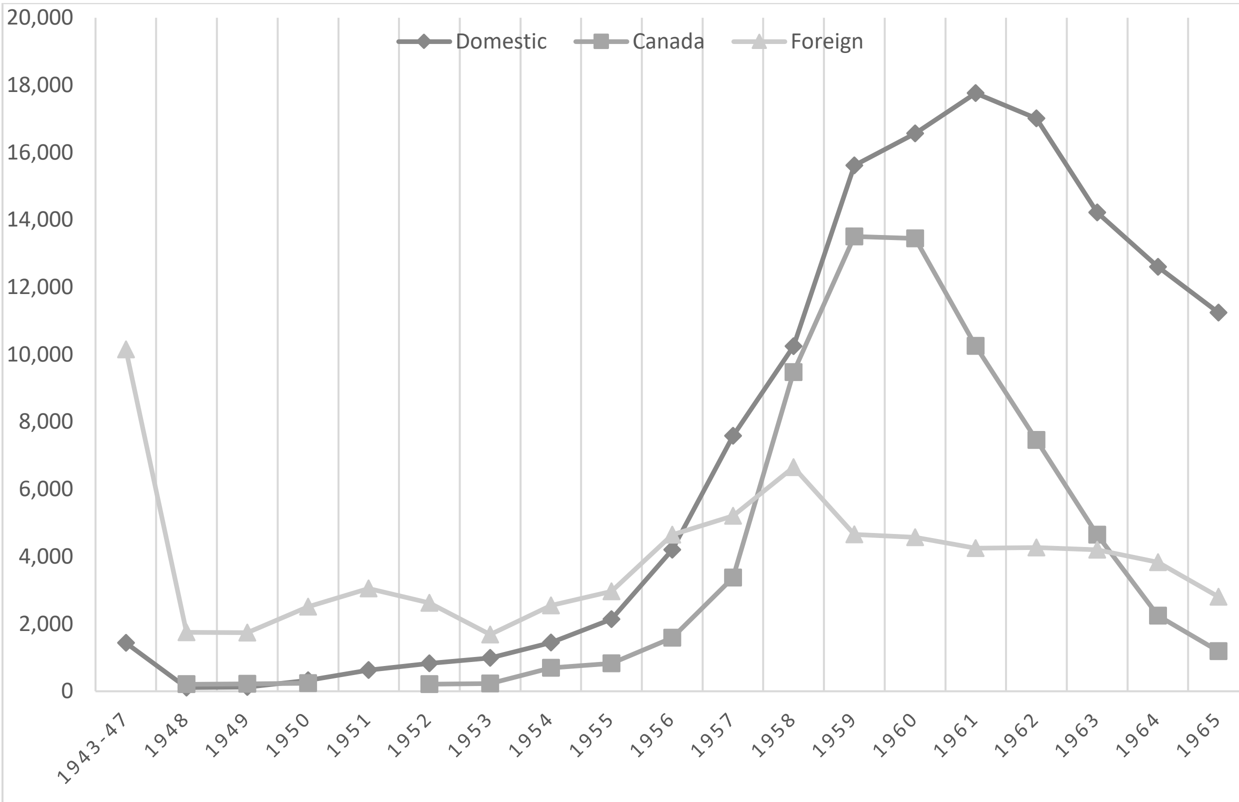
Cold War intensified, the Department of Defense desired a large spectrum of atomic weapons, from small tactical weapons to large thermonuclear bombs. Eisenhower's New Look supported the military's nuclear ambitions, but it was the AEC's task to deliver the weapons.

Under Eisenhower's administration, nuclear weapons were re-categorized from special weapons to the underlying foundation of foreign policy and military might. As a result, AEC production sites became even more pivotal to the nation's defense. Throughout the 1950s, the Strategic Air Command increased its potential bombing targets from 1700 targets in 1954 to 2400 targets in 1959.[20] The increased demand for nuclear weapons also came at the same time that additional inventories of uranium concentrates from Canada and the United States were becoming available. Since 1943, the Belgian Congo had been the single largest supplier of uranium ore to the United States. From 1948 to 1953, the AEC purchased between 2,000 and 3,500 tons of uranium concentrate a year from all of its sources. In these years, production from mines in Canada and the United States was often less than 1,000 tons combined. In 1954, uranium output from American, Canadian, and overseas sources all increased. In 1955, they increased again, and the AEC purchased nearly 6,000 tons of uranium. By 1956, uranium production from the United States and Canada nearly doubled from the year before and overseas sources were not far behind. That same year, the AEC purchased 10,400 tons of uranium in total, with almost 1,600 tons coming from Canada.[21]

[20] Schwartz, *Atomic Audit*, 200–201. Also see David Alan Rosenberg, "The Origins of Overkill: Nuclear Weapons and American Strategy, 1945-1960," *International Security* 7, no. 4 (1983): 3–71. These targets were spread out across the Warsaw Pact countries, the entirety of the Soviet Union, and much of China.

[21] See Figure 3.

Figure 2.1 Atomic Energy Commission Purchases of Uranium Concentrate in tons, 1943-1965.[22]



By 1955, the nuclear weapons production complex looked much different than it had in 1945. The changes were most profound in terms of scale, but also in terms of the centralization of uranium refining and the type of environment surrounding the uranium plants. Situated roughly eighteen miles northwest of downtown Cincinnati, the Fernald plant was located on 1,050 acres of farmland. In the surrounding area, thousands of people lived on farms, suburbs, and cottages. Only two miles from the production plant, local children spent their summers at Fort Scott, the oldest Roman Catholic summer camp in the United States.[23]

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[22] Compiled by the author from various sources including Bothwell, *Eldorado*; J. Taylor and Michael D. Yokell, *Yellowcake: International Uranium Cartel* (New York: Pergamon Press, 1979); Semiannual Reports of the Atomic Energy Commission to Congress, 1959-1963.

[23] "Camp Closes," *Orlando Sentinel*, May 8, 1989.

Instead of several small facilities located in industrial centers across the eastern United States, the AEC's uranium feed materials came from a new, modern, centralized uranium refinery at Fernald. In Cincinnati, some citizens cheered the arrival of nuclear industry to their city. On 31 March 1951, the headline of the *Cincinnati Enquirer* exclaimed that a "huge" AEC atomic plant would be constructed in Hamilton County. The *Enquirer* happily quoted AEC officials who claimed that the new plant would be very safe: "Mr. Chandler [civil engineer and AEC Fernald Area Manager] emphasized that no atomic weapons will be made on the site and that operations will not create environmental toxic or radiological hazards. Nor will there be explosive hazards, he said."[24] But, not everyone was excited. The Fernald plant needed space that was already occupied by farmers, some of whom claimed their family's land as a reward for service in the American Revolutionary war. Others worried that Fernald would act as a target for Soviet bombers in the case of a nuclear war.[25] However, while the creation of an AEC facility would have undoubtedly attracted the attention of Soviet war-planners, the same facilities also promised to bring more economic benefit and higher workplace safety standards than contemporary industrial plants. Since the beginning of the Manhattan Project, jobs at atomic facilities were coveted by tradespeople as well-paying and supposedly safe.[26]

Still, residents and former employees of Fernald recall very little infrastructure in the area when construction began in 1951. Raymond Wolf, a process engineer at Fernald from 1951 to 1966, remembered that his first office was in an old farmhouse in the middle of a cornfield.[27] Helen Underwood, a secretary for the construction company, recalled that her office was in a

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[24] "Hamilton County to get Huge Atomic Plant," *Cincinnati Enquirer* (March 31, 1951).
[25] Silverman, "No Immediate Risk," 292.
[26] See Brown, *Plutopia*; Hales, *Atomic Spaces*.
[27] Raymond Wolf, interview with Fernald Living History Project, May 13, 1999.

renovated chicken house.[28] Nevertheless, by 1954 construction at Fernald was finished and employees could drive to work at the plant on paved roads, and enjoy proper office space. With the establishment of the Fernald refinery, the local population also increased. As Underwood later described: "What used to be a rural community is no longer rural."[29]

Former workers at Fernald remember that the pay was good, and that the opportunity for unlimited overtime allowed them to afford a middle-class lifestyle. Hillery Webb began working at Fernald in the 1950s. As he later described the situation:

> …if you wanted to work overtime all you had to do is go over there and say I'd like to work 16 hours tonight. And we did a lot of those. And I was making good money and I was just as happy as I could be. I was getting my bills paid, I was feeding the kids good and buying nice clothes for them, paying on an automobile or two, a boat, home. I was doing real good.[30]

Other workers remember being motivated by the Cold War. Loyd Smith, who also worked at Fernald in the 1950s, saw how his job was connected to the larger international tensions at the time. Smith recalled working 14-hour days, 7 days a week for an entire year. He understood that the pace at Fernald was due to the Cold War and that production of uranium outweighed all other factors. He also recalled that production levels at Fernald were directly related to the American "Massive Retaliation" deterrent strategy. As he explained:

> …retaliation will be possible because of what we're doing here [at Fernald] because the idea was if Khrushchev would say we have 20 nuclear bombs and they're ready to go, we could say we got 40 and it's a deterrent. And that's the way most everybody looked at it. And felt like it was a matter of survival.[31]

Smith's emphasis on the US nuclear deterrence strategy was certainly shared by the leadership of the AEC and the American military. During the Second World War, the Manhattan

[28] Helen Underwood, interview with Fernald Living History Project, August 7, 1998.
[29] Underwood, interview with Fernald Living History Project, August 7, 1998.
[30] Hillery Webb, interview with Fernald Living History Project, August 19, 1999.
[31] Smith, interview with Fernald Living History Project, May 28, 1999.

Project was focused on the proof of a concept: that an atomic weapon was feasible. To that end, the Manhattan Engineering District assembled a conglomerate of industrial interests to produce uranium products. With the acceleration of the Cold War, the AEC was now tasked with producing as many megatons of explosive power as possible. To meet this end, the AEC spent $35 billion (in 1996 dollars) between 1951 and 1955 to expand and modernize its production system with facilities to quickly and efficiently produce nuclear weapons.[32] In terms of production, the AEC was incredibly successful in achieving those goals. In three short years from 1959 to 1961, the United States produced 19,500 warheads, equivalent to 25 weapons per workday. By 1960, the megatonnage of the entire American arsenal had reached 20.5 billion tons of TNT, or 1.4 million Hiroshima-sized bombs.[33] Whereas the Manhattan project was successful in producing an experimental weapon, the Atomic Energy Commission helped create a massive arsenal of nuclear weapons during the Cold War.

While creating this vast nuclear arsenal, the Atomic Energy Commission and its contractor at Fernald, the National Lead Company of Ohio (NLO), sought to enhance its safety reputation during the design and construction of Fernald. The recent experience of the operation of the older Manhattan Project refineries was reflected in Fernald's design. Studies conducted by the AEC at the older sites revealed that uranium and other contaminants easily seeped into soil and groundwater when exposed to the elements.[34] As a result, contractors built Fernald with a comprehensive sewer system that was designed to trap radioactive contaminants within the entire fenced area of the plant. Engineers also designed a collection system to catch uranium dust, thereby reducing radiation exposure to the lungs of workers and nearby residents. Even Fernald's

[32] Schwartz, *Atomic Audit*, 67.
[33] Schwartz, *Atomic Audit*, 45.
[34] D.E. Lynch, "Soil and Water Uranium and Radium Survey," June 20, 1950, Box 2, Series 27, Record Group 326, NARA, Atlanta.

chosen location made sense from an industrial hygiene point of view. In *Plutopia*, Kate Brown argues that engineers purposefully built the Hanford Site in a remote location near a fast-moving river to protect the local population from radioactive pollutants.[35] In a similar way, Fernald was constructed on farmland away from the industrial center of Cincinnati. The additional safety features and physical placement of Fernald gave both workers and citizens concrete reasons to trust in the safety of the plant.

However, while it was relatively easy to trust the technological systems that promised environmental protection and worker safety, it was more difficult to ensure that those systems actually worked. After ten years of operations at Fernald, an internal committee set up to investigate groundwater contamination was unambiguous about the failures of Fernald's safety systems. In a 1962 report, the committee found that the sewer system, which contained over nine miles of sewer lines, failed to operate as intended. Rather than isolating uranium from rainwater, the sewer system instead funneled uranium away from Fernald and into the local water system. Engineers had recognized the problem as early as 1954 but failed to enforce a solution. The amount of uranium lost to the storm sewers steadily grew until it reached 11,800 pounds in 1961.[36] The dust collection system almost immediately ran into problems as well. While the collectors seem to have effectively removed uranium dust from the interior of the plant, the collected uranium was difficult to contain. Similar to a burst vacuum cleaner, the dust collector often failed and released uranium. Once free of the dust collectors, the uranium acted like other contaminants, and moved into the groundwater via the sewer system. [37]

[35] Brown, *Plutopia*, 59.
[36] In 1956, losses via the storm sewer totaled 1,800 pounds.
[37] Based on experience from the Manhattan Project, engineers understood that uranium oxides left exposed to the elements were quickly washed away by precipitation. As designed, the sewer system was supposed to drain rainwater before it could pick up uranium and other contaminants inside Fernald's fence. See: National Lead

Beyond the failures of technical systems, environmental damage was also enabled by poor choices made by the AEC. In general, the AEC kept particular criteria in mind when selecting a location for their facilities. New projects planned after the Second World War needed to be located close to existing resources, such as water, electricity, housing, a large workforce, and fuel. They also needed to be built in a defensible area of the United States. As Soviet bomber range increased, this meant locating atomic plants farther away from the coasts or the northern border. In the particular case of Fernald, the AEC decided on preliminary requirements of a fast-flowing stream of at least 500 cubic feet per second, at least 30,000 kilowatts of power, and a square mile of relatively flat land, all located near a major industrial city.[38] The site for Fernald was selected by the AEC out of a total of 63 locations in seven states.[39] Fernald's location matched all the requirements of the AEC. In addition to the flushing of effluents provided by the Miami River, the Fernald site was located directly on top of a large, supposedly unused, aquifer. The presence of this aquifer simultaneously excited and worried AEC administrators. While it could potentially provide water for the refining processes at Fernald, it also presented a liability if the aquifer was contaminated by Fernald operations. Thus, the AEC commissioned the first of many groundwater surveys that attempted to figure out which direction the water was moving, how quickly, and whether Fernald was adding contaminants to the aquifer.[40]

The groundwater studies conducted by the AEC and United States Geological Survey (USGS) often gave mixed information. The first groundwater survey in 1951 by the USGS cautioned that any contamination of the groundwater would eventually reach surface streams.

Company of Ohio, "Report of Ground Contamination Study Committee," 30 September 1962, Box 5, Series 27, Record Group 326, NARA, Atlanta, 10, 13-14.

[38] History Associates Incorporated, "History of the Production Complex: The Methods of Site Selection," 1987, 62, https://www.osti.gov/scitech/servlets/purl/5745137.

[39] National Lead Company of Ohio, "Report of Ground Contamination Study Committee," 3.

[40] National Lead Company of Ohio, "Report of Ground Contamination Study Committee," 3.

This report warned that contamination was likely to migrate from the groundwater into surface water via underground streams.[41] By 1962, a different survey report argued that while "it is probable that several tens of thousands of gallons per day of effluent could seep from the [waste] pit without being detected," it would require an estimated "25 to 30 years [for the groundwater] to move 14,000 feet to the Miami River."[42] Over the space of ten years, there were conflicting conclusions drawn about the groundwater under Fernald. Whereas early reports highlighted the vulnerability of the groundwater to contamination, later reports argued that contaminated groundwater did not necessarily pose a threat and would take many years to reach water supplies.

As problematic as the geological surveys were, it is not surprising that the operators of the plant turned to these surveys for information. Studies written by trained geologists presented an objective measurement of environmental harm. NLO had a difficult task of producing as much uranium as possible as cheaply as possible while keeping environmental harm to a minimum. NLO's production goals were objective and easy to measure. Either Fernald was producing enough uranium within its budget, or it was not. As opposed to a production goal, environmental harm was harder to measure. The operators could conduct studies that measured uranium in the water, soil, and air, but the results of those studies were not straightforward. There were no strong regulations in place with which NLO could compare their measurements, and the Ohio State Board of Health did not set public limits for contaminants in the environment. Instead, Fernald operated under guidelines established through informal agreements between NLO, the AEC, and the State of Ohio. A 1962 NLO report into ground contamination summarized this relationship by stating, "The State does not publish a list of MAC's [Maximum

[41] National Lead Company of Ohio, "Report of Ground Contamination Study Committee," 3.
[42] Andrew M. Spieker and Stanley E. Norris, "Ground-Water Movement and Contamination at the AEC Feed Materials Production Center Located Near Fernald, Ohio," September 1962, Box 4, Series 27, Record Group 326, NARA, Atlanta, 13, 16.

Allowable Concentration] for contaminants in public waters. The limits under which the FMPC [Feed Materials Production Center] operates were established by; (1) letters of agreement, (2) verbal agreement, (3) formal negotiation, (4) unilateral proposals and (5) suggestions." Often, these limits were agreed upon only after the AEC produced some form of classified evidence to convince the State of Ohio officials to agree to a particular limit.[43] Since the AEC had a monopoly of information regarding classified nuclear secrets, it gave them a large advantage in any negotiation. In a sense, there were no outside experts or powers of public investigation that the State of Ohio could call upon to evaluate the environmental effects of Fernald. The AEC could hide any harmful consequences behind the wall of nuclear secrecy.

The problem, then, was that environmental safety was not objectively defined. Safe limits were determined arbitrarily and without public consultation. In 1951, in anticipation for the beginning of operations at Fernald, the Ohio State Department of Health suggested a maximum limit of 0.035 parts per million (ppm) of uranium downriver from the Fernald effluent discharge.[44] In response, the AEC suggested a limit of 0.35 ppm, ten times higher than the Department of Health's original suggestion. The Department of Health agreed to the higher limit and this agreement governed the limit for uranium leaving the Fernald plant until at least 1962.[45] Even this elevated limit, however, was rarely maintained. In 1959, the average concentration of uranium in water taken downstream from the Fernald outfall was 1.83 ppm. The single highest reading was 15.68 ppm taken in August. Even with these incredibly high readings, operators

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[43] National Lead Company of Ohio, "Report of Ground Contamination Study Committee,"19-20. The report goes on to complain about the reluctance of the State of Ohio to publish hard limits for various contaminants. Instead, the report argues, the State of Ohio preferred to handle each contaminant from each facility on a case-by-case basis. Incredibly, the limits were often set through negotiation, with seemingly little to no reference from scientific studies.
[44] It is unclear as to why the State Board of Health suggested such a limit in the first place. It seems likely that the Board was attempting to perform its due diligence in case of legal trouble with NLO in the future. See Melosi, *Effluent America*.
[45] National Lead Company of Ohio, "Report of Ground Contamination Study Committee," 20.

argued that they were only high because rain during dry seasons was causing a large amount of uranium to wash out at once.[46] Without strong regulations enforced by an outside agency, NLO and the AEC could spin their pollution readings whichever way they preferred while continuing to argue that they operated a safe plant that protected the surrounding environment and people.

While NLO and the AEC claimed that they were interested in running a plant that was clean and safe, their main priority was producing uranium for nuclear weapons. The construction and initial operation of Fernald took place during a larger, more systematic, expansion by the AEC. The Department of Defense and the AEC annually determined the amount of fissile material that needed to be produced to defend the country. As the atomic stockpile grew, the American military found more targets. By 1956, General Norstad's original fifteen primary targets had grown to thousands of targets.[47] To hit each of those targets, the Air Force assumed that they needed several bombs, since some would be lost to the enemy's air defense. What had originally been a war plan designed to destroy the Soviet Union's ability to wage war had become, in the opinion of certain American military leaders, "overkill". A U.S. Navy study from 1960 found that in order to cause the same damage from a 13 kiloton Hiroshima-sized bomb, nuclear war-planners had assigned 300 to 500 kilotons of weapons to a single target.[48]

By 1955, the AEC operated thirteen separate reactors to produce plutonium for the thousands of nuclear weapons needed in the war plans.[49] The AEC needed to feed each of those reactors with a steady stream of high-purity uranium metal. Without production from Fernald,

[46] National Lead Company of Ohio, "Report of Ground Contamination Study Committee," 13.
[47] "Mapping the US Nuclear War Plan for 1956," *Restricted Data: The Nuclear Secrecy Blog*, accessed February 4, 2019, http://blog.nuclearsecrecy.com/2016/05/09/mapping-us-nuclear-war-plan-1956/.
[48] Rosenberg, "The Origins of Overkill," 7.
[49] Hewlett and Holl, *Atoms for Peace and War*, 6 and 161.

the production of plutonium would stop, and with it, the manufacture of nuclear weapons. From the beginning, Fernald was operating at near capacity.[50]

In the Cold War context, environmental pollution and worker safety became secondary concerns to uranium production at Fernald. By the mid-1950s, construction at the plant was complete and full-scale production of uranium had begun. In order to meet production quotas from the AEC, NLO organized Fernald to run on three shifts, seven days a week. Workers reported to one of ten separate buildings at Fernald organized based on function. As uranium flowed through each plant, workers refined the uranium into successive intermediate compounds until it was reduced to pure uranium metal. Uranium was crushed, burned, dissolved in acid, boiled, reduced to metal, and rolled into shape. The production of uranium metal at Fernald required acids, hydrogen gas, nitrates, fluorides, and large amounts of water at high temperatures. Pipes, furnaces, boilers, digestion tanks, and other heavy equipment surrounded workers. While most of this was quite normal in any chemical plant in the United States, the workers at Fernald dealt with the added dangers of radioactive uranium dust in a self-regulating industry under incredible pressure operated by a company eager to introduce new engineering systems in the world's first purpose-built uranium refinery.[51]

Perhaps unsurprisingly, the first years of operation at Fernald were the worst for worker safety. At the beginning of full operations in 1954, Fernald employed approximately 1,700 workers in well-paying positions. The first worker fatalities occurred that year. In March 1954, an explosion in Plant 6 of the Fernald facility killed two workers. Throughout that year, several

[50] Silverman, "No Immediate Risk," 303.
[51] For a good overview of chemical processes at uranium refineries, see Harrington and Ruehle, *Uranium Production Technology*. For the particular industrial activities at Fernald, see *Production of Uranium Feed Materials* (Capital Film Laboratories, 1959), available at https://www.youtube.com/watch?v=VOm7_Lf8PVo.

more explosions rocked the plant, although no more fatalities occurred.[52] In addition to the acids and furnaces of a regular chemical plant, the Fernald refinery workers faced unique dangers when handling pure metallic uranium. Uranium in this form can combust, especially when piles of chips and shavings build up. Fires, explosions, and plentiful uranium dust contributed to an alarming record of radiation exposure. In 1955, over 90 percent of Fernald workers had exposures to their lungs above the AEC limit of 15 rem per year.[53] Yet, NLO responded slowly to workplace safety concerns. The share of workers being exposed to yearly radiation doses above 15 rem did not fall below 40 percent until 1965.[54]

In addition to the pressure to produce uranium brought on by the Cold War, the AEC expected Fernald to reduce the amount of scrap uranium within the larger production system. While various uranium plants ceased production in the 1940s and 1950s, the scrap material that had been stored there generally stayed at its plant of origin. Some of the scrap materials were sent from the older uranium facilities to the Lake Ontario Ordinance Works, but much of it remained on-site at places like Vitro, Middlesex, and the St. Louis Airport Site. This situation presented a rather large problem for the AEC, since the materials were stored in appalling conditions with little money in the budget to improve them. In a 1953 letter, officials at the Middlesex Sampling Plant described thorium residues packaged into cardboard barrels. While Quonset huts protected these barrels from the elements, Middlesex officials warned the operators

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[52] Silverman, "No Immediate Risk," 306.

[53] The Roentgen Equivalent Man (rem) is a unit of dose equivalent. Dose equivalent attempts to measure the biological impact of radiation, especially risk of cancer. In contrast, units of absorbed dose such as the rep measure the amount of energy deposited into biological tissue.

[54] Schwartz, *Atomic Audit*, 401. While Manhattan Project scientists quickly determined what constituted a single, fatal dose of radiation, they had much more difficulty studying long-term exposure to lower doses of radiation. See Brown, *Plutopia*, 50-60. The current limit for Canadians working in the nuclear industry is the equivalent of 5 rem per year. Canadian Nuclear Safety Commission, "Radiation doses," http://nuclearsafety.gc.ca/eng/resources/radiation/introduction-to-radiation/radiation-doses.cfm.

at Fernald that improper storage conditions would cause problems. In particular, J.J. Costa warned D. J. Blythe that the cardboard barrels could not be stored more than two tiers high, or they would burst open. Costa further stressed that these barrels should be stored in a heated and ventilated environment of at least 2550 square feet for the materials stored at Middlesex. The tone of Costa's letter suggests that Fernald did not have the required storage space, and that there were no plans to address this problem.[55] Over three years later at Vitro, radioactive residues were stored in open-air piles without any form of fencing or warning signs to the public.[56]

The storage of radioactive residues created two problems for the AEC. First, the residues posed a contamination risk to nearby residents. Sanitary engineers were well aware of how quickly uranium could wash out beyond the perimeter of these sites.[57] The longer the residues stayed at the old Manhattan Project sites, the more uranium would seep into the ground and water. Second, without the removal of uranium residues, the Manhattan Project sites could not be returned to their previous owners. At the Vitro plant, for example, the AEC had contracted Vitro to store uranium residues only until the end of 1955. The AEC moved slowly on this issue and had still not removed the residues by September of 1956. With the residues still on the property, Vitro was unable to carry out expansions or to use the land in any other way.[58] Once uranium supplies improved through the years from 1955 to 1957, the scrap uranium sitting in residue piles became a liability rather than an asset to the AEC.

[55] J.J. Costa to D.J. Blythe, "Storage of Penbarnite at F.M.P.C.," January 19, 1953, Box 13, Series 27, Record Group 326, NARA, Atlanta.
[56] "Radiation Survey of Vitro Rare Metals Company, Storage Piles. Canonsburg, Pennsylvania," May 10, 1956, Box 13, Series 27, Record Group 326, NARA, Atlanta.
[57] The postwar uranium surveys plainly presented engineers with the evidence.
[58] F.R. Dowling to S.R. Sapirie, "Disposal of Waste Residues"

To deal with this problem, the AEC tried various solutions. The AEC first attempted to sell residues to industrial corporations, usually for the precious metal content of the ores. When this was met with a weak response from the private sector, the AEC turned to disposal at sea or in private waste dumps. By September of 1954, the Middlesex plant had shipped over 130 tons of contaminated scrap to be dumped into the sea.[59] Two years later at Vitro, the AEC decided to dispose of leftover residues at a privately operated garbage dump owned by the Pennsylvania Railroad. F.R. Dowling, the Director of the Feed Materials Division, listed eight reasons as to why this method of disposal was ideal, including:

> …the [radioactive] material would be widely dispersed and intermixed with tremendous volumes of [non-radioactive] wastes; any further leaching will be to a minimum degree since the material has been stored in an open area, without protection from the weather, from 3 to 11 years; the absences of floods…practically precludes any possibility of backwash; the nearest residence is approximately one-quarter of a mile distant; the Pennsylvania Railroad has no reservations about accepting the material from a health or hazardous viewpoint.[60]

In addition to ad-hoc waste disposal at particular sites, the AEC found more creative ways to dispose of scrap uranium. In 1956, the AEC approved the release of 200 pounds of scrap uranium to the Fire Hazards of Atomic Industry School located at the United States Navy base in Norfolk, Virginia.[61] Such instances were rare, however, and the dominant method of disposal was either to deal with scrap locally or to ship it to Fernald for processing.

AEC administrators expected Fernald to serve not only as a central repository for uranium scrap, but also to eliminate such inventories by refining. This strategy made particular

[59] J.T. Consiglio to F.R. Dowling, "Weekly Report - September 13-17, 1954," September 17, 1954, Box 13, Series 27, Record Group 326, NARA, Atlanta.
[60] F.R. Dowling to S.R. Sapirie, "Disposal of Waste Residues - Vitro Rare Metals Company - Contract No. AT-(30-1)-1683," September 20, 1956, Box 13, Series 27, Record Group 326, NARA, Atlanta.
[61] F.R. Dowling to C.L. Karl, "Release of 200lbs. of Uranium Metal Scrap for Training Purposes," June 26, 1956, Box 13, Series 27, Record Group 326, NARA, Atlanta.

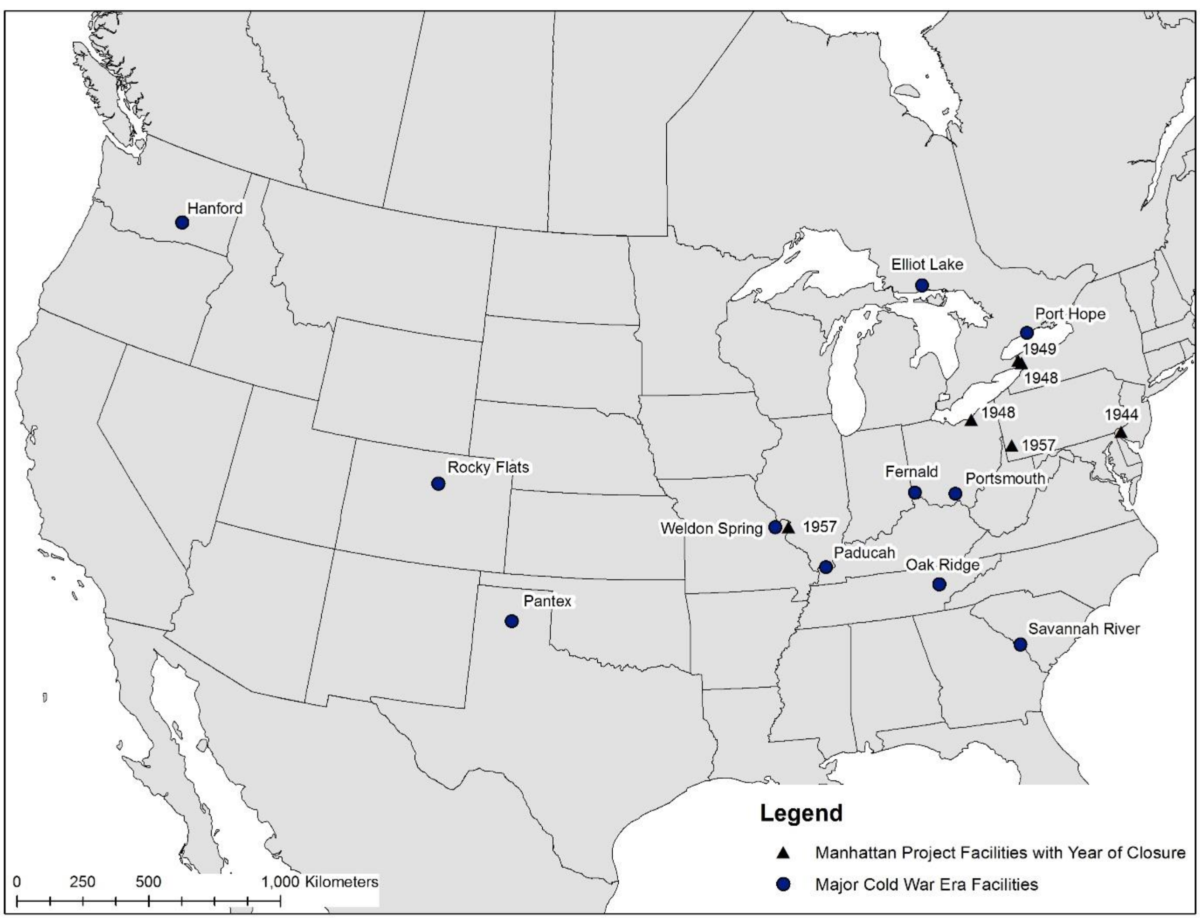
sense when uranium supplies were scarce. Uranium scraps were not necessarily waste, as the AEC still wanted to reprocess the scraps through the uranium system until it was no longer economical to recover the uranium content. However, AEC officials struggled to balance several factors when operating scrap uranium plants. First, it was cheaper and more efficient to refine fresh uranium supplies than to process scrap materials. At the same time, AEC planners desired enough scrap to operate the plants at full capacity in order to obtain the highest economic return. On the other hand, they also desired enough scrap processing capacity to reduce the surplus scrap currently left over from earlier production. While there was a dedicated scrap plant in operation at Fernald and the MCW works in St. Louis, they could only reduce the surplus inventory of scrap by about 300 tons a year.[62] By May 1956, the situation was critical enough that NLO submitted a $1.15 million proposal to expand Fernald's scrap plant. NLO warned the AEC that without the proposed expansion, scrap inventories would continue to rise at Fernald.[63]

As 1957 ended, the AEC's production system looked radically different than it had in 1952**.** The last of the Manhattan Project-era refineries had shut down, and in their place stood two new refineries at Fernald and Weldon Spring. Massive new uranium enrichment plants and new plutonium production reactors had been built by the AEC. New factories at Pantex and Rocky Flats ensured more weapons could be made faster. Perhaps more importantly, the uranium supply situation had undergone a rapid transformation. From just 3,600 tons of uranium in 1952, the AEC purchased over 16,000 tons from all sources in 1957. In 1952, the United States had approximately 800 nuclear weapons but by the end of 1957, they counted over 5,500 warheads in their arsenal. Despite the rapid transformation, AEC planners expected continued growth through

[62] S.R. Sapirie to E.J. Bloch, "Normal Uranium Scrap Processing FY 1956 and FY 1957," November 27, 1956, Box 12, Series 27, Record Group 326, NARA, Atlanta.
[63] G.W. Wunder to C.L. Karl, "Scrap Generation and Consumption - Capital Requirements," May 8, 1956, Box 13, Series 27, Record Group 326, NARA, Atlanta.

the end of the 1950s. Cold War tensions remained high, Eisenhower had secured a second term at the end of 1956, and uranium supplies showed no signs of dwindling. At the AEC facilities, there was to be no slowing down. Working three shifts, seven days a week, Fernald was expected to not only feed the plutonium plants, but also to reduce the amount of scrap and waste now piling up within the entire system. With a sister plant at Weldon Spring now online, the United States' capacity to produce uranium, and the nuclear bombs that went with it, grew tremendously by the second half of the 1950s. The same Cold War tensions that had sparked a massive infrastructure expansion within the AEC did not ease during Eisenhower's term as president. Now armed with a surplus of uranium, Fernald was about to enter the next phase of production with disastrous consequences for the surrounding environment.

Figure 2.2. Expansion and Consolidation of Atomic Energy Commission Facilities, 1944-1957.
Author: Steven Langlois, Historical GIS Lab, 2018



Chapter 3: Uranium Boom and Bust at Fernald, 1959-1989

"You heard more about Fernald after it quit processing uranium than you did before."[1]
Raymond Wuest, Fernald Area Resident, May 1999

During Eisenhower's second term as president, the world's uranium supplies changed dramatically. For the first time, the Atomic Energy Commission moved from a condition of uranium scarcity to a surplus of uranium. This shift, however dramatic, was not unexpected. The number of uranium mines in Canada had steadily increased throughout the 1950s so that by 1959 uranium was the chief mineral export of Canada.[2] In the United States, a hugely successful purchasing program run by the AEC transformed vast mountains of low-level uranium ores into profitable yet environmentally destructive uranium mines. Uranium traveled thousands of kilometers from Canada and the western United States to individual facilities that made up the nuclear weapons production system. At each facility, lax environmental regulation left to local authorities did little to prevent uranium from entering the ground, air, and water. In the late 1950s, the American nuclear weapons production system operated at full capacity in order to keep up with the arms race with the USSR. As the Cold War entered a more dangerous phase, workers at Fernald worked at a fever-pitch to produce uranium, while engineers struggled to contain uranium contamination. In 1959, a combination of plentiful uranium supplies, Cold War tensions, and poor environmental regulations caused pollution levels to spike at Fernald. This created a radioactive legacy that went undiscovered by the local population until the mid 1980s.

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[1] Raymond Wuest, interview with Fernald Living History Project, May 4, 1999.
[2] Exports of uranium were greater than that of much longer established industries such as aluminum, iron, or nickel. Bothwell, *Eldorado,* 383.

By the mid-1950s, uranium destined for nuclear weapons traveled thousands of kilometres through an industrial system of mines, refineries, reactors, enrichment plants, and chemical plants. No longer a patchwork of jury-rigged factories, the new weapons production system was purpose-built to manufacture as many nuclear weapons as possible. Corporations mined uranium at several major production sites. In Canada, the vast majority of uranium was mined at Uranium City in northern Saskatchewan and at Elliot Lake in Ontario. In the United States, the Four Corners[3] region supplied vast volumes of low-density ore. Once the uranium ore had been concentrated at a local mill, the concentrates were sent to a uranium refinery. By 1958, there were three such refineries in North America: the Eldorado refinery at Port Hope, Ontario, the National Lead of Ohio's Fernald refinery in Ohio, and the Mallinckrodt Chemical Works' Weldon Spring refinery in Missouri. At these refineries, uranium concentrates were processed into more useful products such as metallic uranium, uranium tetrafluoride (UF_4), or uranium hexafluoride (UF_6). The uranium was then split into two streams. Uranium tetrafluoride and uranium hexafluoride were sent to enrichment plants to produce enriched uranium, while the metallic uranium was sent to plutonium production complexes at Hanford, Washington and Savannah River, South Carolina. At these large complexes, uranium metal was processed into plutonium. Enriched uranium and metallic plutonium were re-joined at Rocky Flats, a facility in Colorado that manufactured plutonium primaries and worked with enriched uranium. Primaries manufactured at Rocky Flats and secondaries manufactured at Oak Ridge were sent to the Pantex facility in Texas. At Pantex, nuclear primaries and secondaries as well as non-nuclear components were joined together to make finished weapons.[4]

[3] The Four Corners region of the United States refers to Utah, Colorado, Arizona, and New Mexico.
[4] U.S. Department of Energy, *Linking Legacies*. The standard hydrogen bomb design contained two components: a primary, and a secondary. The primary resembled an older-generation fission bomb, with a core made up primarily of plutonium. The secondary was made mostly of enriched uranium and provided the "fuel" responsible for the

This uranium production complex was both a critical piece of military infrastructure as well as an important economic driver. A very visible portion of the military-industrial complex, the uranium production system poured investment capital into the economy and consumed immense volumes of resources.[5] As Cold War tensions escalated, uranium production in North America increased dramatically. In 1954, the AEC consumed over 50 percent of American fluoride production.[6] Peaking in 1956, the uranium production system consumed 12 percent of the electricity output of the United States.[7] By 1960, the AEC was purchasing over 30,000 tons of uranium per year, representing a more than tenfold increase since 1950. Eisenhower's New Look policy and its reliance on the nuclear deterrent had created a nearly insatiable demand for nuclear weapons and their raw components. The result was an immense industrial bomb production system that stretched across the United States, employed thousands of workers, consumed immense resources, and fueled the arms race.

Yet for every bomb that was loaded into a bomb bay, and every worker that received their monthly wages, there were materials left behind. Each piece of uranium that flowed through the system produced a trail of contaminants, residues, and wastes. At the uranium mines, mountains of rock were separated from the uranium oxides found within. At refineries such as Fernald and Weldon Spring, uranium dust and other toxic chemicals spilled from the plants into the surrounding environment. At plutonium production facilities such as Hanford and Savannah River, incredibly toxic and highly radioactive liquid wastes were stored in massive underground tank farms designed to isolate waste from the environment. Not surprisingly, these tank farms

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hydrogen bomb's increased explosive power. When a thermonuclear bomb is detonated, the primary explodes first, causing the secondary to then explode in turn.

[5] By 1955, the AEC had spent over six and a half billion then-year dollars on plant investment. See Hewlett and Holl, *Atoms for Peace and War*, 576.

[6] C.W. Showwalter, "Minutes of April 19th Meeting on Fluoride Consumption by ORO Contractors," April 19, 1955, Box 8, Series 27, Record Group 326, NARA, Atlanta.

[7] Schwartz, *Atomic Audit*, 356.

leaked, and the liquid waste joined radioactive fumes and reactor effluent escaping into the surrounding air, soil, and water.[8]

Except for the added radioactivity, the factories of the uranium production system were not unlike other facilities across the industrialized world. Since the beginning of the industrial revolution, factories, steam engines, mines, and oilfields had spewed forth an enormous volume of pollutants into their surrounding environments. In the late 19th and early 20th centuries, citizens organized against the negative effects of industrialization by arguing that pollution constituted a nuisance. While there were few laws prohibiting pollution, there were strong nuisance laws in the United States that were used to argue that particular instances of pollution were causing harm. Before the First World War, a new sub-discipline of sanitary engineering began to be practiced in cities across the country. Responding to urban pollution, sanitary engineers designed sewage systems, landfills, and water treatment plants. Beginning after the First World War, individual states enacted legislation that gave state boards of health regulatory powers over state bodies of water. By framing pollution as a health and nuisance issue, various parties were able to curtail pollution in a limited, local way.[9]

At the federal level, however, there was very little action taken against pollution in the first half of the 20th century. Nation-wide regulations regarding industrial pollution were small in number and weak in their enforcement. Even as late as 1955, the federal government spent less than 3 percent of its annual budget on environmental programs. As a result, harm from pollution was dealt with on a local, case-by-case basis. Anyone opposing pollution had to rely on the common law and the state boards of health. This strategy, in some instances, could be relatively successful. Courts were familiar with awarding damages based on a loss of property value,

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[8] See Brown, *Plutopia*; US Department of Energy, *Linking Legacies*.
[9] Melosi, *Effluent America*.

though not to stopping the pollution in the first place.[10] The state boards of health could also be effective at preventing pollution through mutual agreement. The Ohio State Board of Health, in particular, had a reputation for being an effective regulator. The state boards of health employed sanitary engineers and their preferred method of engagement with industry was that of cooperation rather than conflict. This approach was evident in the Ohio State Board of Health's interactions with the AEC. In the absence of strong federal regulations, the AEC and their contractor, National Lead of Ohio (NLO), were able to negotiate pollution limits with the state board of health.[11]

The nuisance laws that were used to prevent smoke and water contamination were unequipped to deal with atomic-age pollution. While plenty of other industries were heavy polluters in the 1950s, the uranium industry was different in several aspects. First, the pollutants were radioactive. While scientists had understood since the beginning of the 20th century that radiation was potentially harmful, the installations of the AEC were the first major industrial polluters to send radioactive particles into the soil, air, and water across the United States. As opposed to more "common" pollutants such as oil or chlorides, the patchwork of health and environmental regulators in the United States had little to no prior experience with radioactive pollution. Throughout the 1940s and 1950s, researchers had pieced together the unique biological and ecological pathways of radioactive materials. In particular, scientists quickly understood that the human body readily absorbed multiple radioactive isotopes and deposited

[10] This is not to say that the courts never issued injunctions to stop pollution. For example, in 1918 a county court in Pennsylvania used well-established common law precedents to stop a by-product coke plant from polluting a town's drinking water. The plant was then free to pollute another stream, so long as it did not impact drinking water somewhere else. See Joel A. Tarr, "Searching for a 'Sink' for an Industrial Waste: Iron-Making Fuels and the Environment," *Environmental History Review* 18, no. 1 (1994): 21-22.
[11] National Lead Company of Ohio, "Report of Ground Contamination Study Committee," September 30, 1962, Box 5, Series 27, Record Group 326, NARA, Atlanta. 20.

them within body tissues, instead of allowing them to pass through the body.[12] Since this finding suggested that exposure to radioactive particles was cumulative over a lifetime, health physicists struggled to develop safety guidelines in the same way that they had developed regulations for radiation itself. Exposure to radioactive particles was an inherently random risk. Certain particles that might normally cause very little harm in the air could rapidly damage human tissue once they were deposited in the lungs or gastrointestinal tract. As a result, environmental regulators were unable to independently determine safe levels of uranium and other radioactive particles in soils and streams. Instead, they depended upon the AEC to provide information and to help them to determine reasonable levels of pollution in the environment.[13]

The legislation that established the AEC did nothing to address the problem. The Atomic Energy Acts of 1946 and 1954 gave the AEC wide and exclusive regulatory powers regarding atomic energy, materials, and facilities. The commissioners of the AEC reflected the language of the Acts by delegating a wide range of powers to local field offices. These field offices were given a large responsibility to develop waste and scrap disposal regulations to suit local situations. In particular, the field offices were allowed to negotiate with state-level regulators regarding pollution.[14]

The various state authorities were completely unprepared to deal with the creation of the nuclear weapons production system. State boards of health that had spent the last 50 years

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[12] Often, research into biological effects of radiation was conducted on vulnerable populations such as prison inmates or schoolchildren. By modern research standards, these experiments were highly unethical. See Eileen Welsome, *The Plutonium Files: America's Secret Medical Experiments in the Cold War* (New York: Random House, 1999).

[13] The AEC, through its laboratories and affiliated universities, was the main agency for radiation studies in the 1950s. When the Ohio State Board of Health attempted to determine a safe limit for uranium downstream from the Fernald plant, they were persuaded by research from the AEC. See National Lead Company of Ohio, "Report of Ground Contamination Study Committee," 20-21.

[14] Terrence R. Fehner and F. G. Gosling, "Coming in from the Cold: Regulating U.S. Department of Energy Nuclear Facilities, 1942–96," *Environmental History* 1, no. 2 (April 1, 1996): 8.

cooperating with paper mills to keep chlorate levels down suddenly found themselves across the negotiating table from the AEC inquiring about uranium. The nature of uranium pollution was different from that of the coke-ovens and coal-fires that the state boards of health had been tasked to deal with 50 years earlier. Uranium in water supplies was undetectable by naked human senses. In contrast, phenol pollution from coke ovens almost immediately made drinking water taste bad enough to be unpalatable. As a result, municipalities could quickly threaten lawsuits against polluters.[15] Without this threat, the state boards of health had much less power against other polluters. Indeed, the Ohio State Board of Health preferred a cooperative approach to pollution control until the end of the 1960s.[16] Because of Cold War tensions, the AEC considered itself and its installations to be critical defense infrastructure in the middle of a war. Further, the vast powers of the Atomic Energy Act gave the AEC virtual immunity from litigation and a monopoly on atomic secrets. As a result, the state boards of health were unknowledgeable about the unique pollutants from AEC facilities and unsure about how to enforce agreed-upon regulations. In the absence of any clear evidence which suggested a public health issue, or any strong complaints regarding private property damage, there was little that the Ohio State Board of Health could enforce regarding radioactive pollution at Fernald.[17]

The Cold War mentality further complicated matters. Uranium refineries were almost entirely dedicated to nuclear weapons production until the mid-1960s. As a result, these facilities were considered to be essential to the national security of the United States. Lacking an effective defense against Soviet nuclear weapons, the United States relied on the strategy of deterrence. Symbolized by Eisenhower's New Look, the national security strategy of the United States was

[15] Tarr, "Searching for a 'Sink' for an Industrial Waste," 25.
[16] Tarr, "Searching for a 'Sink' for an Industrial Waste," 27.
[17] See Melosi, *Effluent America*.

directly tied to the number of nuclear weapons it possessed. By building a very large nuclear stockpile, the United States hoped to deter the Soviet Union from attacking. Given the American reliance on this strategy, the uranium production system was inherently a military system, and production was viewed through a wartime lens, even if there was no official war being fought. Radioactive pollution was viewed as a necessary negative effect of this conflict, something that could be tolerated so long as it resulted in eventual victory. It was through this lens that engineers and managers interpreted information. Fernald's operators fully understood what the groundwater reports were saying. The reports argued that groundwater contamination would eventually present a public health problem.

Nevertheless, this attitude became increasingly harmful as larger and larger shipments of uranium were sent to Fernald. As the 1950s wore on, more uranium mines opened in North America. By the end of 1957, the AEC contracts with Canadian uranium companies alone were worth $1.4 billion.[18] The rapidly increasing shipments of uranium were sent to the AEC's uranium refineries which were designed at a time that the United States was importing a fraction of the uranium. The result was a surplus of uranium rather than the shortage of a decade earlier. The AEC's refineries found themselves working around the clock on tight production schedules. In addition, they were tasked with eliminating the surplus of uranium scrap and residues left over from earlier uranium production. The result of this expanded production was an increase in the amount of uranium leaving the Fernald plant and entering the surrounding environment. Significantly, losses of uranium via the storm sewer system at Fernald approximately doubled from 2600 pounds in 1957 to 5400 pounds in 1958.[19] They doubled again from 1959 to 1960,

[18] Bothwell, *Eldorado*, 329.
[19] National Lead Company of Ohio, "Report of Ground Contamination Study Committee," 14, Table 2.

growing from 6300 pounds to 11,200 pounds. The next year, 2600 pounds of uranium were lost through Paddy's Run, a small creek that formed the western boundary of the plant.[20]

While pressure to produce uranium built at Fernald, the Cold War showed no signs of thawing. On 10 November 1958, the Premier of the Soviet Union, Nikita Khrushchev, delivered a speech that was widely interpreted in the West as an ultimatum for the United States to leave West Berlin. Four months later, Eisenhower responded with an address of his own, accusing the Soviet Union of having manufactured a crisis in Berlin:

> Today's Berlin difficulty is not the first stumbling block that international communism has placed along the road to peace. The world has enjoyed little relief from tensions in the past dozen years. As long as the communist empire continues to seek world domination, we shall have to face threats to the peace of varying character and location. We have lived and will continue to live in a period where emergencies manufactured by the Soviets follow one another like beads on a string.[21]

While Eisenhower and Khrushchev agreed to negotiations within months of this address, Eisenhower's choice of language and view of history remain striking in this context. The president implied that Cold War tensions and emergencies were not going to cease based on U.S. actions. Armed with a long list of communist "victories" since 1949, Eisenhower and other American leaders remained steadfast in their commitment to the twin policies of containment and nuclear arms production.

In 1959, production at Fernald was quite steady. Out of a predicted schedule of 10,315 tons of uranium, Fernald received more than expected: 11,505 tons.[22] Broken down between the individual months, September received the lowest delivery of ore at 784 tons, while July was the

[20] National Lead Company of Ohio, "Report of Ground Contamination Study Committee," Table 2.
[21] "Eisenhower on the Second Berlin Crisis," Audio Recording, https://www.history.com/topics/cold-war/eisenhower-on-the-second-berlin-crisis-video.
[22] Data for the year 1959 was compiled from a series of weekly reports from the Fernald Area Manager to the Manager at Oak Ridge. Production data from Fernald was recorded in "tons of U". Weekly Reports can be found in Box 16, Series 27, Record Group 326, NARA, Atlanta.

busiest month with 1320 tons of uranium ore delivered. According to NLO, the abnormally high receipts in July were the result of Canadian producers. In the July 1959 monthly report, the plant manager of Fernald, J.H. Noyes, suspected that Canadian uranium mills had waited until the beginning of the new the fiscal year to make large shipments to Fernald. Noyes went on to argue that the increased availability of Canadian ores "…provided an opportunity for better blending of the marginal feeds throughout the month." [23] Evidently, uranium concentrates from different mines had different chemical properties and the operators at Fernald preferred certain batches of uranium over others. On July 31, C.L. Karl reported to his superior at Oak Ridge that "Canadian feed materials continue in good supply and the Sampling Plant is operating at near record level [sic] for sampling and weighing for the month."[24] In the month of August that year, concentrates from Colorado made up only 16.7 percent of the feed blend at Fernald. Further reports in August argued that Canadian uranium improved the performance of the refinery, and that tests were being conducted on a blend of twelve parts Canadian uranium to one part Portuguese uranium. Operators at Fernald were thus aware of where uranium ores were being delivered from and separated the uranium accordingly.

Unpredictable delivery schedules, and the chemical differences in uranium ores led the operators at Fernald to blend different samples of uranium. This situation created the need for the storage and warehousing of uranium, one of the main routes by which uranium entered the surrounding environment. Uranium ores packaged into metal drums at Fernald were stockpiled

[23] J.H. Noyes to C.L. Karl, "Monthly Report of NLO Production Activities," July 29, 1959, Box 16, Series 27, Record Group 326, NARA, Atlanta. 1.
[24] C.L. Karl to S.R. Sapirie, "Weekly Progress Report," July 31, 1959, Box 16, Series 27, Record Group 326, NARA, Atlanta. 2.

in the open air before being accepted for processing. Precipitation quickly corroded metal drums, and the uranium contents were then free to pollute the soil and groundwater.[25]

Just as uranium arrived at Fernald from many locations, Fernald's uranium products were also widely distributed. Refined uranium from Fernald fueled production at the AEC's massive gaseous diffusion plants, as well as their sprawling plutonium production facilities. On average in 1959, Fernald produced 1,000 tons of uranium contained in uranium trioxide (UO_3) per month. Of this, roughly 200 tons were sent to gaseous diffusion plants for enrichment. That same year, an average of 815 tons of uranium per month were reduced to metal for plutonium production. Once uranium compounds had been reduced to metal, they were machined and rolled into "slugs" for use in plutonium production reactors. To further complicate the variety of products Fernald produced, the different facilities at Hanford and Savannah River required different sized slugs, each with multiple designs. Hanford's eight reactors consumed over 6,000 tons of uranium slugs in 1959, while Savannah River's five reactors received 1,770 tons that same year. In addition to the regular production shipments, Fernald prepared uranium products to order for the AEC's research reactors and various private industries. However, these orders were not remotely close to the quantities needed for nuclear weapons production.[26]

Like most other chemical plants and refineries, Fernald required large amounts of reactants to successfully run the chemical reactions that were necessary to refine uranium. Since pure uranium was the desired product, much of these chemicals were waste products. For example, the reduction reaction with magnesium to produce uranium metal also produced magnesium fluoride (MgF_2). Contaminants in the form of wastewater and by-products from

[25] D.E. Lynch, "Soil and Water Uranium and Radium Survey," June 20, 1950, Box 2, Series 27, Record Group 326, NARA, Atlanta.
[26] Weekly Production Reports, Box 16, Series 27, Record Group 326, NARA, Atlanta.

uranium refining were stored in clay-lined storage pits before being pumped directly into the Great Miami River, roughly 3.5 kilometers south of Fernald. By 1962, the largest of these pits was 7.5 acres and contained nearly 50 million gallons of waste. That same year, some 800,000 gallons of effluent were pumped into the pit each day, with a similar amount being released into the river. While the engineers at Fernald had taken the precaution of lining the waste pits with clay, a 1962 groundwater report found that it was likely that the clay liner had eroded in some areas, and that it was "probable" that tens of thousands of gallons of waste could leak from the pits without being detected.[27]

The weekly reports also reveal that Fernald was just barely able to keep up with scrap production. The production of scrap materials was a problem that plagued the AEC and Manhattan Project since its inception. Improperly stored uranium materials quickly contaminated surrounding soil and water. By the mid-1950s, the uranium supply had improved to such an extent that local AEC offices were beginning to permanently dispose of scrap materials by burying them in landfills or at sea. At Fernald, the proposed solution was instead to operate a scrap recovery plant which would allow the most useful scrap materials from across the United States to be recycled back into the production stream. By 1958, AEC officials were searching for additional long-term plans to deal with scrap production.[28] The scrap recovery plant at Fernald had operated since 1953**,** the only plant at Fernald allowed to operate more than five days a week by 1959.[29] Still, the 1959 records clearly show that the Fernald scrap recovery plant struggled to reduce scrap inventories. On June 4, 1958, the Director of the Feed Materials Division of the

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[27] Andrew M. Spieker and Stanley E. Norris, "Ground-Water Movement and Contamination at the AEC Feed Materials Production Center Located Near Fernald, Ohio," September 1962, Box 4, Series 27, Record Group 326, NARA, Atlanta. 14.
[28] John W. Ruch to R.C. Armstrong, "Interim Plan for the Management of Recycle Uranium Containing Materials," June 4, 1958, Box 8, Series 27, Record Group 326, NARA, Atlanta.
[29] John W. Ruch to C.L. Karl, August 18, 1959, Box 15, Series 27, Record Group 326, NARA, Atlanta.

AEC, John Ruch, directed the assistant manager of the Oak Ridge Operations Office to implement an interim scrap recycle policy. In particular, Ruch argued that the scrap plant at Fernald should be operated at full capacity and with the "richest" scrap inventory.[30] Evidently, the scrap plant's primary function was to recover uranium while reduction of scrap inventory was a secondary consideration. This shows how environmental protection at AEC facilities was often a side effect of other programs. While the reduction in scrap inventories would have certainly reduced the amount of uranium pollution at Fernald, the primary goal was to recover the uranium content for nuclear weapons.

It is not surprising that AEC administrators prioritized uranium production, especially considering the worsening Cold War tensions between 1959 and 1961. Fidel Castro and his 26th of July Movement successfully ousted the government of Fulgencio Batista in Cuba on January 1, 1959. While relations between the United States and Castro's government were originally cordial, they soon soured as the new Cuban government began a series of social and economic reforms, often to the detriment of American business interests. Throughout 1959, Eisenhower and Khrushchev held a series of meetings which had the potential to reduce tensions and end the on-going Berlin Crisis. However, on May 1, 1960, an American U-2 spy plane was shot down over the Soviet Union. Since the pilot survived, and the airframe was mainly intact, Khrushchev used the incident to publicly embarrass Eisenhower who had previously denied that such flights were occurring. As a result of the political fallout, the Four Powers summit in Paris, which had been scheduled for the middle of May 1960, fell apart after just two days of meetings.[31] Relations between the US and USSR deteriorated in the second half of 1960 and the Berlin Crisis remained unsolved. Communist anxiety in the United States was strong and John F. Kennedy

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[30] John W. Ruch to R.C. Armstrong, "Interim Plan for the Management of Recycle Uranium Containing Materials."
[31] LaFeber, *America, Russia, and the Cold War*, 211.

won the presidential election that fall, in part because of his perceived willingness to close the alleged "missile gap" between the Soviet Union and United States.[32] Despite the intense anti-communist rhetoric of the presidential campaign, Khrushchev recognized an opportunity with the arrival of a new American administration. The two leaders agreed to a meeting in Vienna in June 1961.[33]

Meanwhile, the AEC was concerned with two major items during this time. First, the uranium contracts that were due to be renewed in 1959 and second, groundwater pollution at Fernald. As early as 1956, officials in the Canadian government recognized that American stockpiles of uranium were growing, and that the AEC was unlikely to continue purchasing as much uranium as the Canadians could produce.[34] By July 1958, the American uranium market was actively shrinking, and Eldorado had some difficulty holding the AEC accountable to their previous commitments. In November 1959, the AEC delivered the news to Eldorado: it would not be renewing its contracts past 1963.[35] Upon reviewing the AEC documents, it is not hard to imagine why. Even though records from Fernald imply that operators preferred using Canadian uranium, Fernald could only refine roughly 10,000 tons of uranium per year. Even if we include Fernald's sister plant, Weldon Spring, and assume that it could produce a similar amount, the AEC still purchased over 33,000 tons of uranium in 1959.[36] Moreover, the AEC struggled to find storage space for feed materials, which contaminated the surrounding environment due to poor storage. An ever-increasing surplus of uranium concentrate only compounded this problem. Despite rising Cold War tensions, the AEC decided that by 1959 the surplus of uranium could

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[32] Lafeber, *America, Russia, and the Cold War*, 202-203.
[33] Aleksandr Fursenko and Timothy Naftali, *"One Hell of a Gamble" Khrushchev, Castro, and Kennedy, 1958-1964* (New York: W.W. Norton, 1997), 77–79.
[34] Bothwell, *Eldorado,* 412.
[35] Bothwell, *Eldorado,* 421.
[36] Over 13,000 tons of uranium were purchased by the AEC from Canada alone. This would have been enough material to keep Fernald running at full capacity for over a year.

adequately ensure nuclear weapons production. The large industrial uses of uranium predicted in the earlier part of the decade had failed to materialize and the vast majority of uranium production would continue to be earmarked for bomb manufacturing.[37]

At the same time as AEC officials in Washington decided to limit uranium imports, Fernald operators started to become more interested in groundwater contamination. Groundwater studies had been conducted at Fernald since at least 1951. In 1955, a staff scientist with the United States Department of the Interior, C.V. Theis, visited Fernald and inspected its waste disposal infrastructure. In his official report to the Division of Reactor Development with the AEC, Theis identified two major issues that could cause groundwater contamination: the pipeline which transported wastes into the disposal pits, as well as the pits themselves. In addition to these problems, Theis outlined the infrastructure that was already in place to prevent contamination: the concrete pad, the storm sewer system, and the lift station which transferred waste water into the Miami River when Paddy's Run was dry. At the conclusion of his report, Theis remained cautious about disposing wastes directly into the soil at Fernald. He warned that Fernald's relatively small size and proximity to other industrial and residential groundwater customers meant that the movement of groundwater contaminants in the future was unpredictable.[38]

Despite the range of environmental protection technology that Theis described, industrial waste contaminated the aquifer under Fernald. In November 1961, groundwater from a test well at Fernald was revealed to contain heightened levels of pollutants. In order to find the source of

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[37] Civil nuclear power requirements did not match the 1959 uranium extraction peak until about 1985. See World Nuclear Association, "World uranium production and reactor requirements (tonnes U)," graph. Available at http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/world-uranium-mining-production.aspx.

[38] C.V. Theis to Arthur Z. Gorman, "Visit to Atomic Energy Commission's Fernald Ohio Area," September 26, 1955, Box 8, Series 27, Record Group 326, NARA, Atlanta.

the contamination, NLO officials tried various methods, including the dumping of a radioactive marker into the waste pits to see if it would turn up later in groundwater tests. Despite NLO's efforts, they were unable to determine the source, and requested the support of the AEC and U.S. Geological Survey (USGC).[39]

By September 1962, the USGC completed their contamination study at Fernald. According to the report, the AEC contacted the USGS to "…ascertain whether seepage from four large waste disposal pits located near the west edge of the plant production area has entered the principal aquifer from which water is supplied to the AEC plant and to many other ground water users in the area."[40] Evidently, the administration of the AEC was less concerned with environmental damage in general, and more concerned with the pollution of economically valuable water sources. At the time, Fernald was drawing over 1 million gallons of water a day from the aquifer to produce uranium. This worry is reflected in the findings of the USGS report and the language of the internal NLO narrative. The authors of the USGS report argued that it would take ground water approximately 2 to 5 years to travel from the waste pits to the main plant supply wells, and 25 to 30 years to reach the town of New Baltimore and the Miami River.[41] In the NLO narrative, Fernald was already regularly dumping waste directly into the river with a reading of 10,000 parts per million (ppm) of chlorides and 12,000 ppm of nitrates.[42] Rather than worry about directly polluting the river, NLO was worried about polluting the

[39] J.A. Quigley to J.H. Noyes, "Status of Ground Water and Stream Contamination Studies," September 18, 1962. Box 5, Series 27, Record Group 326, NARA, Atlanta.
[40] Spieker and Norris, "Ground-Water Movement and Contamination at the AEC Feed Materials Production Center Located Near Fernald, Ohio," 1.
[41] Spieker and Norris, "Ground-Water Movement and Contamination at the AEC Feed Materials Production Center Located Near Fernald, Ohio," 13. The way that the authors frame their finding is quite important, since it suggests to the AEC leadership that the contamination problem will not become a public problem for another 25 to 30 years.
[42] Quigley to Noyes, "Status of Ground Water and Stream Contamination Studies," 2.

economically important groundwater. The USGS recommended that NLO should dig more test wells, and that they should repair the bottom of the waste pits to better contain contaminants.[43]

At the end of September 1962, the NLO Ground Contamination Study Committee released their report. This report summarized the contamination problems that Fernald had faced since the beginning of operations. In this report, officials from NLO argued that some of the assumptions made in the original design of Fernald were quickly proven false when Paddy's Run was frequently found to be contaminated by waste. At the same time, the report highlights the efforts that NLO had taken to remedy the contamination problem. According to the report, NLO had spent over $1,000,000 and conducted at least six groundwater surveys since the beginning of operations. Beyond this, the committee recommended several solutions for the contamination problem, but few of them dealt with infrastructure. Interestingly, the committee recommended a change in philosophy: "The philosophy concerning ground contamination and plant cleanliness must be firmly restated and enforced throughout the project."[44] In perhaps a more practical direction, the committee also recommended that the "organizational responsibility for the control of ground contamination should be defined," to which someone had written in the margins "after 10 years still no definite responsibility."[45] Two pages later, the committee summarized their findings with an underlined statement:

> It is therefore concluded by this committee that the recommended capital improvements, along with increased awareness of the problem and efforts by all concerned, will eliminate or minimize undesirable contamination in Paddy's Run, the ground water, and the Miami River.[46]

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[43] Spieker and Norris, "Ground-Water Movement and Contamination at the AEC Feed Materials Production Center Located Near Fernald, Ohio," 21.
[44] National Lead Company of Ohio, "Report of Ground Contamination Study Committee," 8.
[45] National Lead Company of Ohio, "Report of Ground Contamination Study Committee," 8.
[46] National Lead Company of Ohio, "Report of Ground Contamination Study Committee," 10.

At the top of the same page, someone had written in pencil: "No!! White-wash. No teeth."[47] These two statements capture the tension that existed in AEC installations during the Cold War. On the one hand, the pressure to produce uranium, and the understanding that this was a critical military defense mission to support the national American deterrent strategy, was immense. On the other, Fernald, like any other industrial polluter, wanted to avoid conflicting with the law by polluting economically important bodies of water. Yet in an era of weak-to-nonexistent environmental protection, NLO was left to regulate itself. The groundwater committee report clearly highlights how the lack of regulation resulted in mediocre attempts at environmental regulation as NLO and AEC officials watched pollution levels rise and did little to stop a slow motion environmental and health disaster.

In October 1962, the world watched the Cuban Missile Crisis unfold. In a dramatic display of Cold War tensions, the U.S. and U.S.S.R. confronted each other over the Soviet deployment of nuclear weapons on the island of Cuba. By this time, the American nuclear arsenal was immense and contained a stunning array of different weapon systems. In 1962, the United States maintained a significant strategic nuclear advantage over the Soviet Union. At the time, the U.S. was capable of deploying some 25,000 nuclear weapons from aircraft, naval ships, submarines, intercontinental ballistic missiles, and artillery systems.[48] The Soviet Union, on the other hand, possessed less than 3,500 warheads during the crisis.[49] Frantic production at Fernald and other sites throughout the nuclear production system helped to resolve the Cuban Missile Crisis by ensuring an overwhelming strategic advantage in the favour of the United States.

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47 National Lead Company of Ohio, "Report of Ground Contamination Study Committee," 10.
48 See Schwartz, *Atomic Audit*, table 1-3, 86-91.
49 Hans M. Kristensen and Robert S. Norris, "Global Nuclear Weapons Inventories, 1945–2013," fig. 2, 78.

While the US nuclear arsenal continued to expand after the peaceful resolution of the Cuban Missile Crisis, rampant environmental pollution at Fernald did not become public knowledge for another twenty years. Six years before an explosion at the Chernobyl nuclear power plant broke international headlines, residents in Ohio were dealing with their own radioactive clouds.[50] In January 1980, Citizens against a Radioactive Environment (CARE) announced that Paddy's Run, the stream that ran beside Fernald, contained over twice the legal limit for radiation in public drinking water. The Environmental Protection Agency (EPA) fired back, arguing that CARE was applying the wrong standards for radiation limits. Richard Heatherton, by then the director for health and safety at Fernald, said that CARE's application of the EPA's limits was probably correct, although the radiation level of the stream fluctuated throughout the year. This is consistent with archival records, which show varying levels of uranium contamination throughout the calendar year. Through a Freedom of Information Request, CARE was able to access similar documents that showed that "equipment failures, routine leaks, and carelessness" allowed Fernald to discharge thousands of pounds of uranium into the environment.[51]

CARE's whistleblowing received little public attention until 11 December 1984, when local residents received the first confirmation from NLO and the Department of Energy, which succeeded the AEC in 1977, that uranium was escaping from the plant itself. The front page of the *Cincinnati Enquirer* warned residents that NLO was checking for a "possible" uranium leak.[52] Within weeks, concerned residents began to organize themselves into groups. On January

[50] The people living near the Fernald plant would have been well aware of the partial meltdown at Three Mile Island in 1979. However, I use the Chernobyl example because it was more environmentally destructive and is better known internationally.
[51] Bob Elkins, "NLO Spill Reports Range Back to 1952," *Cincinnati Enquirer,* December 15, 1984.
[52] Ben L. Kaufman, "NLO Checking Possible Uranium Leak," *Cincinnati Enquirer,* December 11, 1984.

11, 1985, 200 people attended a meeting convened by Fernald Residents for Environmental Safety and Health (FRESH).[53] Working as a grassroots organization, FRESH engaged with government representatives and the EPA to try to raise awareness regarding pollution at Fernald. At the same time, American national newspapers began to sound the alarm about uranium contamination at Fernald. Headlines from major national newspapers like "Uncle Sam's Hot Spot" and "Leaks of Uranium Dust an Ohio Issue" kept Fernald in the national spotlight throughout 1985.[54] By August, the DOE confirmed that Fernald had contaminated local drinking wells.[55]

Local resident Lisa Crawford replaced Kathy Meyer as FRESH president in late 1985 and spent the next several years meeting with Fernald officials, attending and organizing meetings, and travelling to Washington D.C. to testify in front of senate subcommittees. She remembers the day that Fernald stopped production as a day of celebration: "we actually went to one of the FRESH member's houses and cracked open a bottle of champagne and said, 'we won.'"[56]

In March 1985, the Environmental Protection Agency had presented a notice of noncompliance to the Department of Energy related to the environmental contamination at the Fernald site. The following year, the Ohio Environmental Protection Agency sued National Lead of Ohio and the DOE for violations of water pollution and hazardous waste laws. In response, the DOE invoked the Comprehensive Response, Compensation, and Liability Act (CERCLA), better known as the "Superfund" Act.[57] As a DOE report explains, the Superfund process was used "to

[53] Anne Brataas, "NLO Probe Quantifies Dust Leaks," *Cincinnati Enquirer*, January 13, 1985.
[54] Laurie Garrett, "Uncle Sam's Hot Spot: Troubles at a Vital Federal Nuclear Plant," *The Washington Post*, July 28, 1985. "Leaks of Uranium Dust an Ohio Issue," *New York Times*, January 2, 1985, B11.
[55] Ben L. Kaufman, "DOE Confirms Fernald Contaminated Area Wells," *Cincinnati Enquirer*, August 6, 1985.
[56] Lisa Crawford, interview with Fernald Living History Project, August 17, 1999.
[57] In 1980, the United States Congress passed the Superfund legislation motivated in part by public anger surrounding environmental pollution typified by places such as Love Canal. The Superfund legislation allowed for remediation in cases where the original polluter could not or would not pay for environmental clean-up.

characterize the nature and extent of contamination at the [Fernald] site…establish risk based clean-up standards, and select the appropriate remediation technologies to achieve those standards."[58] Having mismanaged the levels of pollution at Fernald for 30 years, the DOE was passing the responsibility directly on to the EPA and the American people.

By 1989, the final year of uranium production at Fernald, the amount of contamination was staggering. In 1990, the Centers for Disease Control (CDC) reported that through Fernald's refining activities, 470,000 kilograms of uranium dust and 160,000 curies of radon-222 were released into the atmosphere, and 90,000 kilograms of uranium were released into the surface water.[59] In a separate study completed eight years later, the CDC further concluded that the pollution released by Fernald increased local residents' lung cancer risk by 1 to 12 percent. Among the 43,000 to 50,000 people who had resided within ten kilometers of Fernald between 1952 and 1988, the CDC estimated that anywhere from 25 to 309 excess lung cancer deaths would occur as a direct result of pollution from Fernald.[60] In 1997, the Department of Energy reported that the Fernald site contained 490,000 cubic meters of low-level waste, and had polluted 2,100,000 cubic meters of solid media[61] and 270,000 cubic meters of water. [62]

These numbers came as a shock to residents since contamination was not previously a matter of public record. Joe Wessels remembers that in his childhood he believed the Fernald

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58 United States Department of Energy, Office of Legacy Management, *Fourth Five-Year Review Report for the Fernald Preserve*, August 2016.
59 Robert Wones et al., "Medical Monitoring: A Beneficial Remedy for Residents Living Near an Environmental Hazard Site," *Journal of Occupational and Environmental Medicine / American College of Occupational and Environmental Medicine* 51, no. 12 (December 2009): 1375.
60 Owen J. Devine, Judith R. Qualters, Joan L. Morrissey, and Patrick A. Wall, *Fernald Risk Assessment Project Final Report*, Centers for Disease Control, 1998, 7.
61 A DOE term for soils, groundwater, surface water, sediments, debris, and other materials. U.S. Department of Energy, *Linking Legacies*, 2.
62 U.S. Department of Energy, *Linking Legacies*, 62, table 3-8; 79, table 4-4; 81, table 4-5. It is important to note that these numbers represent only the soil and water that the DOE recognizes as posing a threat to the public.

plant produced dog food because of its neutral logo and name.[63] Many residents repeated similar stories in their interviews with the Fernald Community Alliance. As Sue Verkamp explained:

> But we all thought that it was a Purina Dog Food Plant because, you know, of the checkerboard. Everyone just assumed that they were making feed materials, they were making feed materials for animals. Just thought, well, the parent company must be Purina. And figured that it's in farm country, so it's probably horse feed and cow feed. That's what I thought it was; that's what my husband thought it was. And it wasn't until we got more involved in finding out about it that we learned that no, it was actually feed materials for weaponry.[64]

In response to the jolting headlines, residents living near the Fernald plant had launched their first lawsuit against National Lead of Ohio in 1985. Arguing that since radioactive emissions had not been public record prior to 1984, the plaintiffs sued for emotional distress and loss of property value. In 1989, the plaintiffs settled for $78 million split into three portions: cash payments for emotional distress, payments for loss of property value, and a trust fund established to support a medical monitoring program. The next year, Fernald workers organized and filed their own lawsuit for emotional distress related to the increased risk of cancer and won $20 million in 1994.[65]

In December 1990, nearly 10,000 people residing near Fernald began participating in the medical monitoring program established through their lawsuit. The monitoring program consisted of biannual medical check-ups provided free-of-charge to anyone deemed eligible. In an article published in 2009 by the doctors who administered the program, the authors stressed that it was comprehensive. The medical doctors performed a complete physical and checked for

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[63] Joe Wessels, "Fernald Checks Out, and So Do I," *CityBeat Cincinnati*, September 9, 2008, https://www.citybeat.com/voices/editorial/article/13019105/fernald-checks-out-and-so-do-i.
[64] Sue Verkamp, interview with Fernald Living History Project, January 11, 2001.
[65] Patricia K. Cianciolo, "Compensating Nuclear Weapons Workers and Their Survivors: The Case of Fernald," *Michigan Family Review* 19, no. 1 (2015), 55.

any type of illness independent of its potential link to uranium exposure. According to the authors, this was in order to fulfil the "emotional distress" portion of the lawsuit. By the time the medical program was completed in 2008, doctors had diagnosed nearly 1700 "major" conditions in the original group of 10,000 residents, including diabetes, various forms of cancer, and chronic lung disease. Despite these diagnoses, the administrators of the program contended that, as a whole, the participants had a lower mortality rate than would be expected of the general population. The doctors also argued that participation in the program led to advanced detection of illness as well as an increased awareness of good health practices for the participants.[66]

In 1997, the Fernald Community Alliance began the Fernald Living History Project (FLHP). By conducting over 130 interviews with residents, workers, activists, and management at Fernald, the Fernald Community Alliance sought to preserve the history of Fernald without relying on documentary evidence. During his interview, Stan Chesley, a lawyer for the citizen's lawsuit, explained that National Lead of Ohio had been granted immunity from prosecution as a condition of their contract with the AEC,[67] an important perspective from someone intimately connected with the Fernald story that is not evident in the archival material. Other interviews are filled with accounts regarding poor worker safety.[68] In an interview in June 1999, Nancy Abbott spoke about her husband's illness, and her struggle to obtain rightful compensation from Fernald's management. Abbott's husband worked at Fernald beginning in 1955. By 1982, he had passed away from cancer. Although the surgeon told Abbott that her husband's cancer was

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[66] Wones et al., "Medical Monitoring."
[67] Stan Chesley, interview with Fernald Living History Project, September 9, 1999.
[68] Hillery Webb, interview with Fernald Living History Project, August 19, 1999.

"without a doubt" connected to his work at Fernald, the management refused to award her any form of worker's compensation.[69]

Of course, the environmental and health data outlined in this chapter was not available to the residents and workers affected by Fernald until the late 1980s. Their anger and frustration was, and continues to be, justified. The secretive nature of nuclear weapons production ensured that workers and residents were not consulted by the AEC about health and environmental concerns related to Fernald and were instead kept in the dark. Cold War tensions in the 1950s and 1960s demanded high production from Fernald. But as production at Fernald increased as a result of large uranium supplies, the pollution of the environment increased as well. Residents and workers, assured that they were safe, continued to live and work in Fernald's shadow. By the 1980s, a wave of environmental activism, the waning of the Cold War, and intense media attention brought production at Fernald to an end. Although the last uranium left the plant in 1989, controversy and anxiety over environmental contamination at the site continue.

[69] Nancy Abbott, interview with Fernald Living History Project, June 15, 1999.

Conclusion

Beginning in the mid-1940s and continuing to the mid-1960s, the United States purchased mountains of uranium ore for its nuclear weapons program. While uranium had formerly been a waste product in the production of radium, the development of the atomic bomb transformed the demand for, and applications of, uranium. Expecting the need for nuclear weapons to counter a perceived Soviet threat, American administrators working for the newly formed Atomic Energy Commission sought to gain control of uranium supplies across the world. By stimulating the price of uranium with a purchasing program, uranium supplies quickly and drastically increased by the mid-1950s. Canada, in particular, greatly benefited from the demand created by nuclear weapons production. By the end of the 1950s, at the height of the Cold War, uranium was the most valuable Canadian export behind wood products and wheat.[1] Within the United States, the AEC spent incredible amounts of public money to build the giant processing facilities required to transform the uranium into an atomic bomb. For a single piece of uranium to become part of a nuclear weapon, it needed to travel across the United States through several facilities. At each facility, scraps, waste, and extensive pollution were guaranteed by-products of uranium processing. Despite the fact that nuclear weapons production was organized on a federal level, waste policy and pollution control were not. Contractors at each AEC facility were free to develop pollution policy according to local conditions. Cold War tensions and a lack of national environmental regulation resulted in effectively no regulation of the AEC. Consequently, pollution control was always a secondary concern to nuclear weapons production for the AEC during the Cold War.

[1] Bothwell, *Eldorado*, 383.

Nevertheless, uranium scraps and residues were a concern for AEC administrators from the very beginning of the nuclear arms race. In an atmosphere of uranium scarcity and Cold War anxiety, war planners wanted to maximize uranium resources by maintaining scraps for potential use in the future. Yet sanitary engineers quickly understood that these residues were quite dangerous and easily leached into the surrounding soil and water. Due to a lack of strong regulations, however, the managers of AEC regional offices were free to deal with contamination problems as they saw fit. As a result, radioactive scraps were disposed of in various ways as the uranium supply improved. Buried in various landfills and waste pits, the residues were forgotten about. The rise of the environmentalist movement and the actions of the Environmental Protection Agency brought the uranium activities of the AEC, now operating as the Department of Energy, under intense public scrutiny. After 40 years of little to no outside regulation, the DOE suddenly found itself accountable to an angry and anxious public.

In 1989, Congress ordered the Department of Energy (DOE) to cease uranium production at Fernald and begin preparation for environmental remediation. In 1992, the DOE awarded an environmental remediation contract to the Fluor Corporation. The plan was ambitious, estimated to cost $12 billion over 30 years. By 2006, Fluor had disposed of thousands of tons of radioactive waste and soil, as well as completed the demolition of all of Fernald's original contaminated structures.[2] Governmental and regulatory agencies hailed the cleanup of Fernald as a commercial and environmental success. If we only look at the surface, it is easy to see why. The project was completed under budget and on time. The Fernald site is now a beautiful green square with wetlands and walking trails. Local nature groups claim that the space is a sanctuary for wildlife, and the visitor's center has won an award for green design by the U.S. Green

[2] "Fernald Environmental Remediation" https://www.fluor.com/projects/fernald-environmental-remediation.

Building Council. Beneath the surface, however, there is less to celebrate. While Fluor was able to remove the waste pits and other contaminated media on site, they were unable to remove the uranium that had entered the water table. The underground plume of uranium continues to pollute the Great Miami River, but at levels that the DOE maintains are “safe”.[3] As a result, the environmental legacy of Fernald is complicated. Without the history of mismanagement and pollution, the green space should be a celebrated accomplishment of the community. It is not wrong to say that the Fernald site is now a sanctuary for wildlife in an otherwise industrialized landscape. At the same time, the underground contamination has rendered the site “permanently uninhabitable” for humans. Uranium refining irreparably damaged the aquifer, and the trust of the community has been broken.

Elsewhere, a similar story played out at nuclear sites across the United States. In 1997, Congress ordered the Army Corps of Engineers to conduct a study into potentially contaminated sites dating back to the Manhattan Project. Launching a program known as the Former Utilized Sites Remediation Action Program (FUSRAP), the Corps is currently engaged with remediation at various sites which have been since abandoned and their radioactive legacy forgotten.[4] In the post-Cold War era, the huge installations at Rocky Flats, Hanford, Oak Ridge, Portsmouth, Paducah, and Savannah River were closed down. Across the United States, the DOE spent billions of dollars in the 1990s and 2000s to remediate these Cold War relics, with mixed results. At Rocky Flats, for example, remediation was carried out in a similar manner to Fernald. The immediate area was decontaminated but is unfit for any residential or commercial enterprise. At Hanford, the most contaminated industrial site in the United States, the cleanup operation is not

[3] “What’s In The Water? Local 12 Investigates Fernald," *Local 12 WKRC*, March 1, 2018, news broadcast accessed on YouTube, https://www.youtube.com/watch?v=TnIHWepc7do.
[4] Included in the FUSRAP program are many sites which I briefly mentioned in Chapter one such as Vitro, DuPont Deepwater Works, and others. https://www.usace.army.mil/Missions/Environmental/FUSRAP/

yet completed, even after 20 years of intense work. Across the nuclear weapons production system, environmental contamination, expensive remediation, medical studies, and lawsuits are the familiar story.

In the present day, radioactive contamination is an ongoing legacy of the Cold War. Documentaries like *Atomic Homefront* and books like *Plutopia* remind us that contamination continues to harm people long after a bomb has been manufactured.[5] Current environmental remediation and medical monitoring are costs of nuclear weapons production that war planners of the Cold War did not, and perhaps could not have, considered. Hundreds of millions of dollars in compensation rightfully paid out to workers and citizens is part of the nuclear legacy. At the same time, the United States and the Russian Federation each maintain approximately 1,600 nuclear warheads armed and ready to fire at a moment's notice.[6]

During the Cold War, the uranium production system and its refineries were essential to the nuclear arms race and the testing that went along with it. While the United States had built only a handful of nuclear weapons by the end of the Second World War, the American weapons production system had manufactured over 28,000 warheads by the end of 1963.[7] Yet, as the Fernald case study demonstrates, the production of nuclear weapons was a particularly damaging enterprise. Environments and communities were profoundly harmed by the industrial activities carried out across the United States in support of the production of nuclear weapons. The Cold War may have found a political resolution, but the environmental and health ramifications continue into the present.

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[5] "Atomic Homefront," accessed July 13, 2018, https://www.atomichomefront.film/; Brown, *Plutopia*.
[6] "Treaty on Measures for the Further Reduction and Limitation of Strategic Offensive Arms," 8 April 2010, *Treaties and Other International Acts Series.* Commonly known as "New START."
[7] Hans M. Kristensen and Robert S. Norris, "Global Nuclear Weapons Inventories, 1945–2013," fig. 2, 78.

This thesis contributes to a more complete and nuanced understanding of the Cold War by highlighting the role that uranium refining played in the nuclear arms race as well as the environmental and health impacts of weapons manufacturing. Overshadowed by larger, more environmentally destructive AEC facilities, the Fernald plant has received scant attention by historians. Yet the story of Fernald is critically important to the wider historiography of the Cold War as well as the discipline of environmental history. This case study demonstrates how the AEC and its contractors consistently emphasized the production of nuclear weapons at the expense of environmental and biological harm caused by the refining of uranium during the Cold War.

Though billions of dollars have been spent, and former industrial sites like Fernald are now green, people continue to suffer from illness and the threat of shortened lifespans because of nuclear weapons production. This is the inherent irony when scholars and the public engage with the threat of nuclear weapons. We spill oceans of ink writing about what could happen if nuclear war ever occurs. We rarely stop to think about the people who have suffered because of nuclear weapons manufacturing. We worry about what might happen if the missiles ever leave their silos. We decline to worry about what has already happened to workers and residents who are forced to deal with the legacy of the Cold War in a very personal way.

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